NOAA Technical Memorandum NESDIS AISC 4

DEVELOPMENT OF A TROPICAL CYCLONE DAMAGE ASSESSMENT METHODOLOGY

Isobel C. Sheifer and John O. Ellis

Washington, D.C.
January 1986

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Marine Environmental Assessment Division
Assessment and Information Services Center

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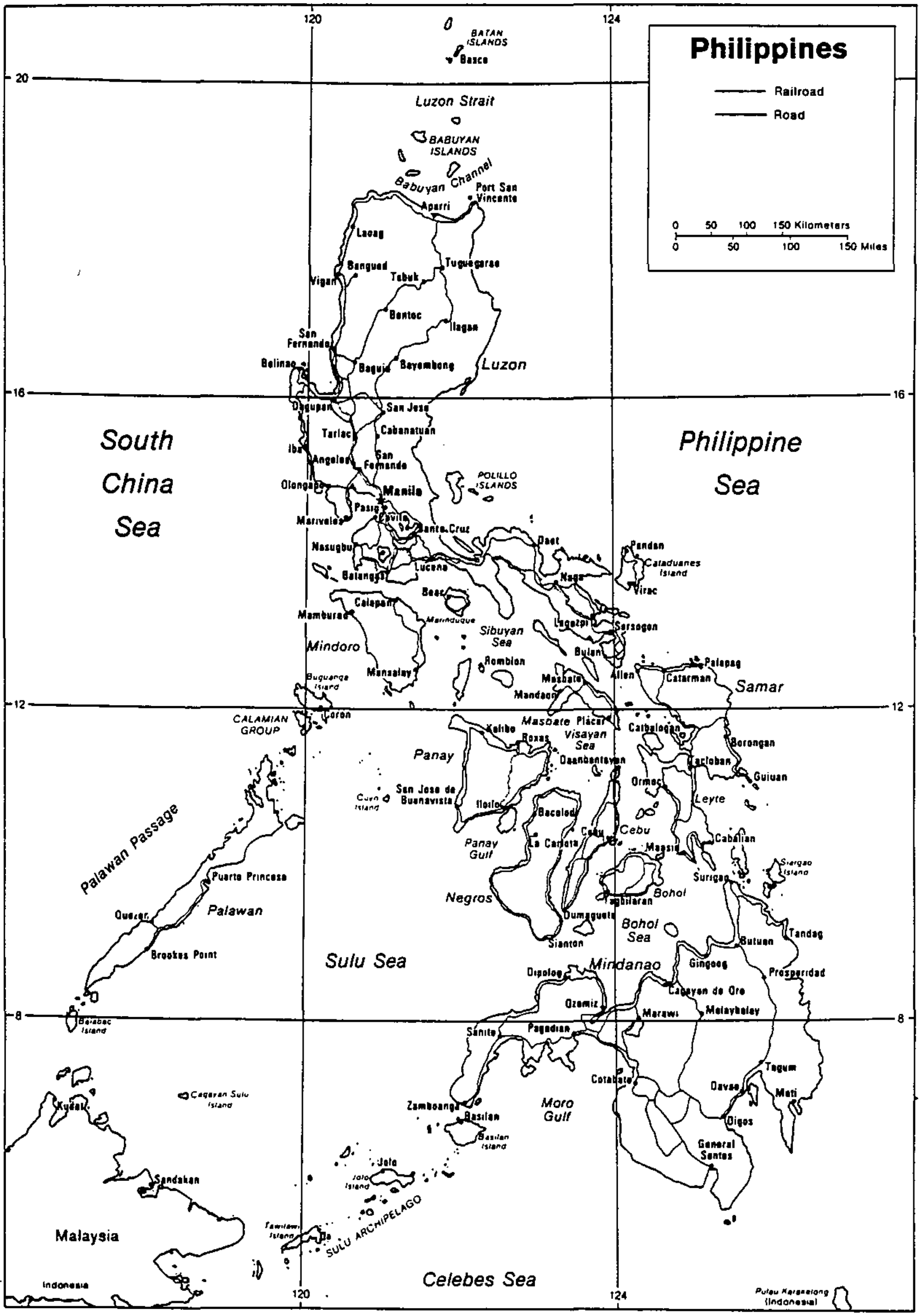
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Guiuan
San Jose de Buenavista
Ormoc
Leyte
Iloilo
Bacolod
Cebu
Cabalian
Panay Gulf
La Carlota
Maasin
Siargao Island
Surigao
Palawan Passage
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Bohol
Tagbilaran
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Brookes Point
Sulu Sea
Sianton
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Dipolog
Mindanao
Gingoog
Prosperidad
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Ozamiz
Balabac Island
Marawi
Malaybalay
Sanite
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Cotabato
Davao
Mati
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Kudat
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Moro Gulf
Basilan Island
Digos
General Santos
Jolo
Jolo Island
Sandakan
SULU ARCHIPELAGO
Tawitawi Island
Malaysia
Celebes Sea
Indonesia
Pulau Karakelong (Indonesia)
South China Sea
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1. INTRODUCTION

This pilot study is part of the continuing efforts of the Assessment and Information Services Center (AISC) to expand and improve the decision assistance value of its assessment products. The objective of this study is to develop a methodology to assess the impact of tropical cyclones on the economies of developing countries. Results of the study will be included in the AISC world-wide assessments which cover other types of economic impacts related to weather.

We have chosen the Philippines for this pilot study because tropical cyclones are more frequent there than any other place in the world. Indeed the local name for typhoon is "Baguio," which is also the name of the summer capital of the Philippines. The average annual frequency of tropical cyclones passing the Philippines is 18 which is twice as many as the Caribbean, the second area of the world most prone to these occurrences. This high frequency in the Western Pacific will give us more cases to study. Another reason for selecting this area is our familiarity with it. We have done other studies in the Philippines and are familiar with data sources in the area.

A tropical cyclone is essentially a rotating cyclone of the tropical oceans. Many people refer to tropical cyclones by the popular names "typhoon" and "hurricane," terms which properly characterize tropical cyclones that have attained an average surface wind speed of 64 knots or greater. A tropical cyclone of lesser intensity is either a "tropical storm" or a "tropical depression" depending on its wind speed. When fully developed, a typhoon/hurricane can cause severe damage. However, it is neither the largest nor the most intense of all storms. Extratropical cyclones are bigger than hurricanes/typhoons and tornadoes are more intense. The Atlantic hurricane has meteorological characteristics identical to the Pacific typhoon and the willy-willy of Australia. Tropical cyclones also occur in the Malagazy Republic area, the Eastern Pacific and Hawaii, the Central South Pacific (Tahiti), the Indian Ocean and the Bay of Bengal.

A cyclone is a low pressure atmospheric system. It begins as a low pressure due to differential heating or intense convection. As soon as the low pressure is formed, the air starts to flow from high to low, but due to the rotation of the earth the air ends up moving counterclockwise (clockwise) around a cyclone in the Northern (Southern) hemisphere. The development of the system into a typhoon/hurricane is sustained only by the excess outflow in the high troposphere over the inflow at the lower level. The main supply of energy in a tropical cyclone comes from the latent heat of condensation. This is the reason that typhoons/hurricanes do not form at temperate latitude since there is a minimum sea surface temperature to support the evaporation process that later will sustain the release of energy in the form of condensation. Tropical cyclones also dissipate over land due to the loss of energy supply and higher friction in the lowest layer.

The main characteristics of typhoons/hurricanes are: 1) the "eye," the center of the storm where there is relative calm and which is sometimes clear; 2) the spiral wall clouds of intense precipitation and strong winds; and 3) a large expanse of strong, gusty winds and heavy rains. There are two types of motion in these tropical cyclones--the tangential velocity of rotation and the propagation velocity of the storm. These velocities add or subtract depending on the location relative to the center; thus, there is a small, dangerous semicircle where the intense winds occur. Severe damage will occur on the right side of the track. This is true for both wind and storm surge damage.

Tropical cyclones can cause damage in three ways: 1) damage to public works/infrastructure due to strong winds, 2) storm surges in the coastal and low-lying areas, and 3) heavy rainfall. All these three weather phenomena are related and interacting. The stronger the wind, the more intense the rainfall, and the higher the induced surge. Although the wind damage is the most spectacular outcome of these tropical cyclones, greatest loss of life and property has occurred from storm surge. In the United States, the most deaths attributable to a hurricane occurred in 1900 in Galveston, Texas, where the storm surge swept over this low-lying area killing over 6,000 people. In November 1970, a tropical cyclone in the Bay of Bengal killed about half a million people and contributed to the change of government (East Pakistan became Bangladesh).

The Philippines has at times suffered staggering damages from tropical cyclones. Despite the use of satellite imagery and other advanced technology to predict the tracks of storms and provide early warnings, the first priority has been in the saving of human life rather than in cutting down measurable money losses. Projects that have been constructed to minimize and mitigate tropical cyclone impacts have frequently not proved effective and have themselves been damaged or destroyed. Indeed, with increasing modernization of facilities and growing industrialization in Pacific nations, damages from tropical cyclones continue to mount throughout the region, even after accounting for inflation. The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) reported in 1974: "Despite the investment of large sums of money in improving the defensive system in the typhoon area, the cost of damage continues to climb rapidly . . . the best man can do, with all the technical skill at his command, is not sufficient to reverse it." (ESCAP, 1978).

For this study, we collected meteorological and economic data from various sources. Meteorological data were obtained from the earlier study by Gray (1970) for 1884-1945, from publications of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA, 1978, 1979-83), and the Joint Typhoon Warning Center (JTWC) Guam annual publication (JWTC, 1970-1984). Sources of economic data were published reports by the Philippine government agencies, reports of the U.S. Agency for International Development's Office of Foreign Disaster Assistance, United Nations and World Bank studies, meteorological summaries containing damage assessment, newspaper articles, and journal commentaries.

This report discusses how the meteorology and other physical variables are related to the damage from tropical cyclones. In Section 2, we discuss the meteorological analysis. This includes the description of the sources of data, types of data used, track of storms, probable threat or strike probability, and meteorological variables of the storm that may be related to damage. Section 3 is divided into two major parts. Subsection 3.1 contains material on the development of economic tables, derivation of a damage index, and a 15-year summary of the index for the Philippines. Subsection 3.2 discusses and analyzes annual summaries of impacts of tropical cyclone damage on the Philippine economy for 1970-1984.

Section 4 summarizes the results of several analyses of the economic and meteorological data considered together. An example of a possible storm predictor of losses in the maximum wind speed 12 hours before landfall (or impact). This is not a simple or unique predictor, since typhoons can severely affect an area even without making landfall. For example, a storm tracking parallel to the coastline may inflict heavy damage in many ways.

Section 5 summarizes the results from this pilot study and recommends areas for future study. Among the things we recommend is the development of a standardized system for reporting damages. As a first step, such a system will facilitate future analysis and will provide a better basis from which to draw further conclusions.

2. METEOROLOGICAL ANALYSIS

2.1 Data

The meteorological data used to compile the statistics were obtained primarily from the PAGASA publications (PAGASA, 1978, 1979-1983) and the JTWC, Guam (JTWC, 1970-1984) annual publication. The PAGASA publication (1978) contains a summary of tropical cyclones from 1949-1978 and the PAGASA publications 1979-1983 are yearly. These summaries contain data for tropical cyclones which include tropical depressions, tropical storms, typhoons, and super typhoons. A tropical cyclone is a large scale (low pressure) system which develops over tropical or subtropical waters and has a definite organized circulation. Tropical depression is a tropical cyclone with maximum winds less than or equal to 33 kt, a tropical storm is a tropical cyclone with maximum winds 34 to 63 kt, a typhoon is a tropical cyclone west of 180° longitude with maximum winds greater than or equal to 64 kt, and a super typhoon is a tropical cyclone with maximum winds greater than or equal to 130 kt.

The PAGASA data for the earlier years (1970-78) contains for each cyclone the track, name and date of the storm, the maximum observed wind speed and location, the minimum sea level pressure (SLP) and location, the maximum 24-hr rainfall and location, and a brief statement of the affected area plus some information on casualties and damages. There is also a section on unusual, extremely severe, or damaging storms with a track chart and description. The more recent data (PAGASA, 1979-1983) has a more thorough write-up of individual storms with a track chart, information on forecast verification, rainfall maps and tabular data for all stations, and summarized tropical cyclone statistics.

The JTWC, Guam data (1970-1984) has track charts with wind speeds and storm speeds, a meteorological description of the storms including some damage information for certain storms, description and results of track forecast techniques, tabular reconnaissance and position data, summaries of statistics on cyclone occurrence, and descriptions of applied research on tropical cyclones (track forecast aids, synoptic climatology, and uses of satellite data).

The (available) data were studied to identify meteorological factors thought from knowledge of storm dynamics to be related to damage from tropical cyclones. Factors considered were the size of the storm (the pressure system), the intensity, the area of damaging winds, and the angle at which the storm approached or impacted land.

Quantitative indices of these meteorological factors were studied and tabulated. Physical size of the storm was determined by the diameter of the 1000 mb isobar circle when the storm impacted the Philippines and was tabulated. This variable was readily available for only a very limited number of storms in the 1979-83 period. A way to determine the diameter is to reanalyze the maps--a tedious process. For dynamical reasons, radius to maximum wind is a more appropriate measure of size. Measures of the intensity are the maximum observed wind speed and the minimum observed sea level pressure. These were both tabulated, even though they are related dynamically. Other variables for quantifying intensity of damage impacts are the maximum storm rainfall amount at a station and the duration of the rainfall. Neither of these appeared to correlate well with the total damage, however. A measure of the extent of the storm is the number of stations with storm rainfall totals of 100 mm or more; this was tabulated. There is a correlation using this variable but it was only available for 5 of the 15 years. No readily available measure of the extent of damaging winds (gale force or greater) was found. The length of time the storm was over land was another possible measure of its extent. This was measured and tabulated as the duration that the center was over land areas. No useful correlation was evident. The time since the last storm was significant in individual cases, however. Wind speed 12 hrs and 24 hrs before landfall (or impact) was studied to see if there was predictive information in comparing these parameters. There appears to be some useful predictive information in the 12-hour measurement but not in the 24-hour one.

The meteorological variables tabulated for all 128 storms were wind speed 24 and 12 hrs before impact (or time of influence), the maximum observed wind speed in the Islands, the minimum observed sea-level pressure in the Islands, the angle of the storm's impact (or approach), and the maximum rainfall. The angle of approach or impact was used, coded by 30° segments from north thru east to south-southwest with east southeast as the direction from which the more damaging storms came.

2.2 Summary of Meteorological Records 1970-1984

In the longer term climatologies (Gray, 1970) of tropical cyclones in all of the western north Pacific, there are approximately 30 storms per year; of these 18 affect the Philippine area. The statistics for the 1970-84 period were compiled from the PAGASA data (PAGASA, 1978, 1979-83) for the Philippine area of forecast responsibility. From these sources the statistics of the number of storms per month, both total and those affecting the Philippines, were obtained. The PAGASA data showed a total of 308 storms (an average of 20.5/yr) and our analysis considered 128 of these (an average of 8.5/yr) as having a possible economic effect on the Philippine area. Figure 1 shows a monthly breakout of total storms in the area, the number affecting the Philippine area (by our criteria) and the number causing substantial, high, and very high damage (see Subsection 3.1.2 for an explanation of damage evaluation).

The ratio (in percent) of the number of storms causing damage (substantial or greater) to total number of tropical storms affecting the area was calculated. This shows that there is a gradual increase (in percent) of more destructive storms from the time of the year there are enough cases to make it a meaningful statistic (May) with 20 percent to the later part of the season (November) with 50 percent. In other words there are relatively more damaging storms in the later part of the season than in the earlier part. Part of this may be due to the maturing of crops in the later time of year so that the crops are more vulnerable to heavy damage.

A plot of the average number of typhoons per month from the earlier study of Gray (1970) for 1884-1945 and the PAGASA (1978, 1979-83) 1948-83 data is shown in Figure 2. This shows an apparent lower frequency of storms in July thru October in the most recent years, but it is possible that there were storms included in the earlier years that would not be included now because of changes in definitions of classes of tropical cyclones. For instance, there may have been storms with winds less than or equal to 34 kts that were included or storms with winds less than or equal to 63 kt that were designated typhoons. Of course,

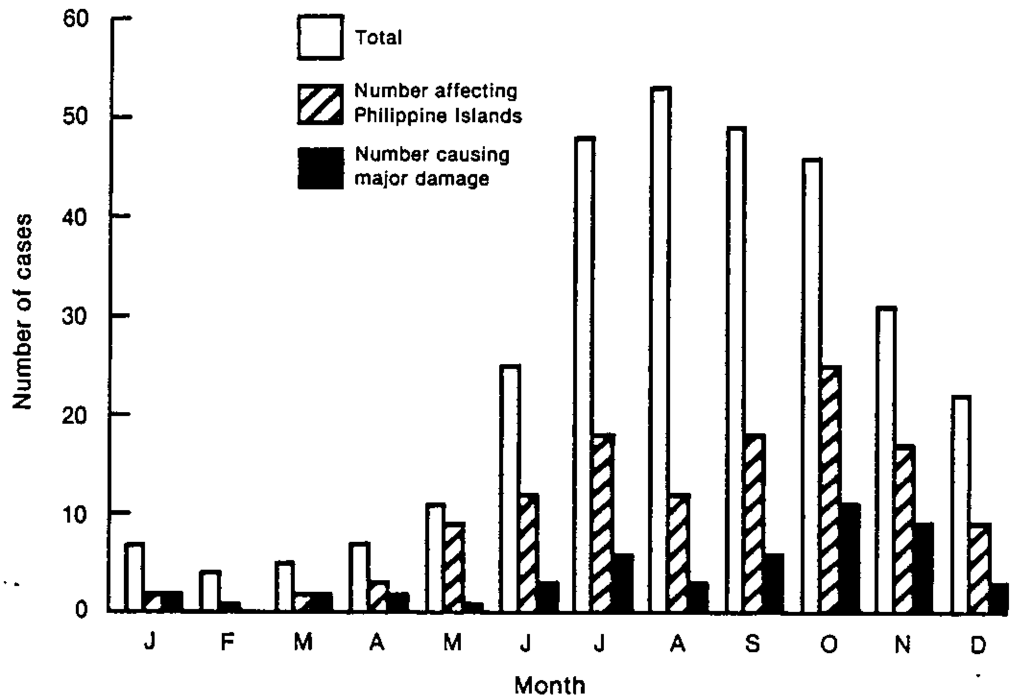

Figure 1.--Total storms in the Philippines, the number affecting the area, and the number causing major damage, 1970-1984.

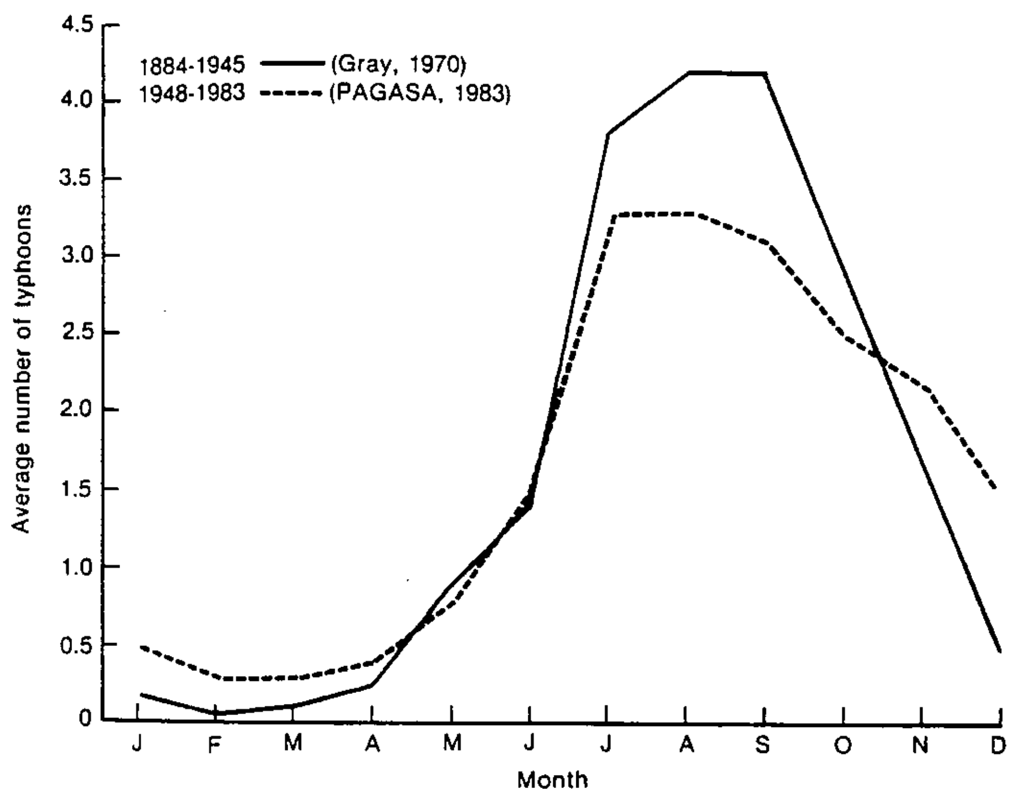

Figure 2.--Average number of typhoons by month for the years 1884-1945 and 1948-1983.

there is improvement in recent-day data observation methods available - satellites and air reconnaissance.

The storms studied in detail were ones we determined could cause economic damage to the Philippine Islands. In the meteorological summaries there were a total of 308 storms in the 1970-84 time period in the area. Of these approximately 236 affected the area meteorologically. This effect would include anything from storm center passage over the islands with the associated wind, rain, and wind-driven storm surge, to the storm's passage in such a way to intensify the summer monsoon so that more rain would occur from the monsoonal circulation. A monsoon is the name given to seasonal winds. It is caused primarily by the greater annual temperature variation over the Asian land mass than over water, causing an excess of pressure over land in winter and a deficit in summer. For the Philippine area this means a general southwesterly flow (i.e., from the southwest) in summer and a northeasterly flow in the winter.

For the 1970-1984 period approximately 75 percent of the tropical cyclones in the area affected the weather of the Islands. Of these we studied about 55 percent for the possible economic affect on the Philippines (308 total, 236 having meteorological effect, 128 studied for economic effect). To be in our meteorological-economic evaluation, a storm was considered by the highest meteorological classification (typhoon, tropical storm, tropical depression) it achieved in its life. Of those storms which tracked over or near the Philippines, we selected for analysis only those which were designated "typhoons" or "tropical storms."

2.3 Monthly Track Charts

Composite track charts for the 128 cases we studied were plotted to study the monthly and seasonal trends of the storms' origins and tracks. These composite charts were then summarized by months for June through November. Because of relatively few cases, the December through May data were combined. Figures 3a-g show the tracks over the Philippines determined subjectively from the composite track charts. The large arrow is the track composite - the direction showing the general direction of tracks as the storm crosses the Philippines, with the width of the arrow giving a relative indication of the envelope of tracks, i.e., their dispersion north or south of this track. Also shown are selected representative individual storm tracks for storms causing greater damage. These individual tracks also show some of the variations that occur in tracks such as looping (Elaine in August) and sudden direction changes (Betty in November). The sample also had some west-to-east tracking storms.

Overall, these figures show a general northerly progression of storm tracks from June to October, then a return to more southerly tracks in November and December through May. This seasonal progression is similar to that of the earlier analysis of Gray (1970) for the 1948-1968 period and thus shows that our study period 1970-1984 does not have any months that are radically different from a longer term climatology.

2.4 Probability Charts for the Philippines

Another way of summarizing tropical cyclone track information is shown in Figures 4a-e. These show the probability (or percent frequency) that a tropical

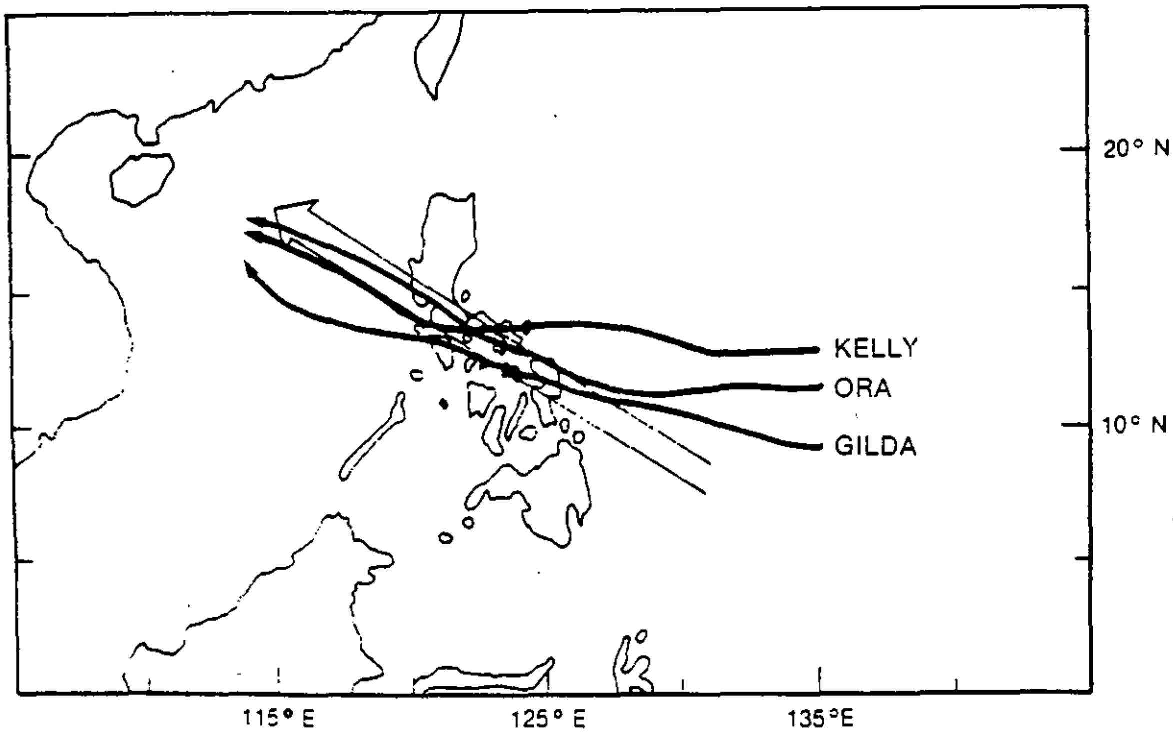

Figure 3a.--Track summary charts showing the storm track trend (wide line arrow) and selected typhoons and tropical storm tracks (narrow line arrow). June.

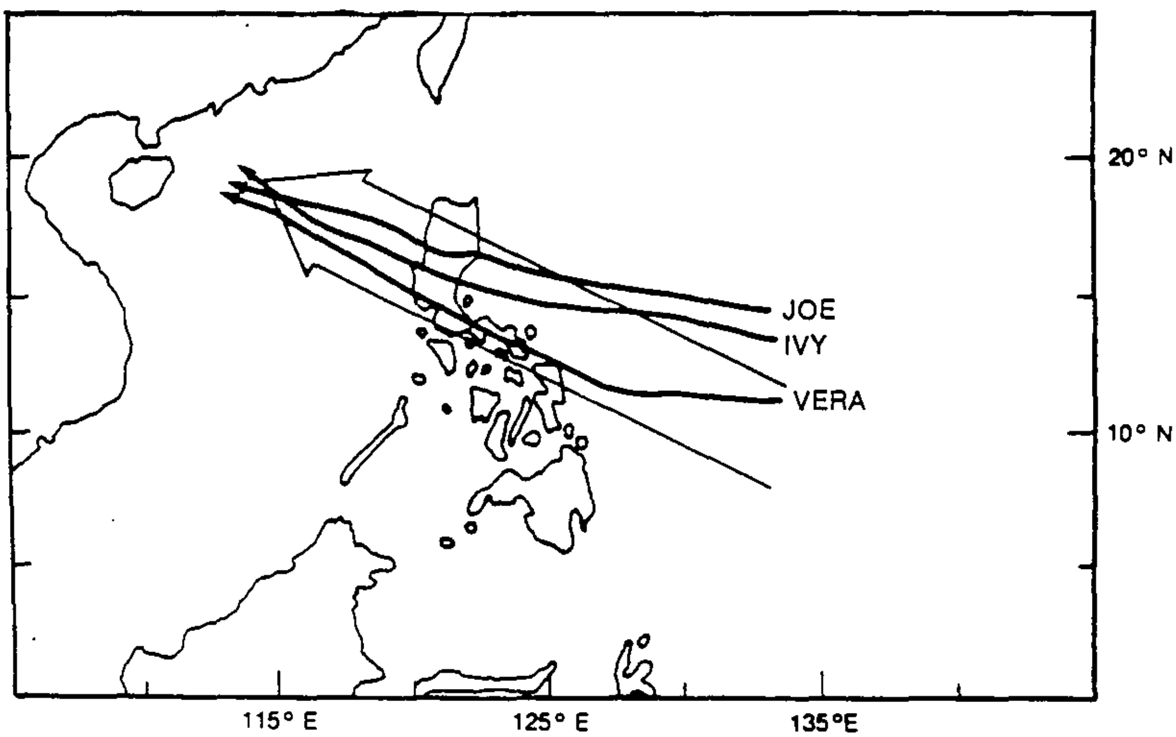

Figure 3b.--Track summary charts showing the storm track trend (wide line arrow) and selected typhoons and tropical storm tracks (narrow line arrow). July.

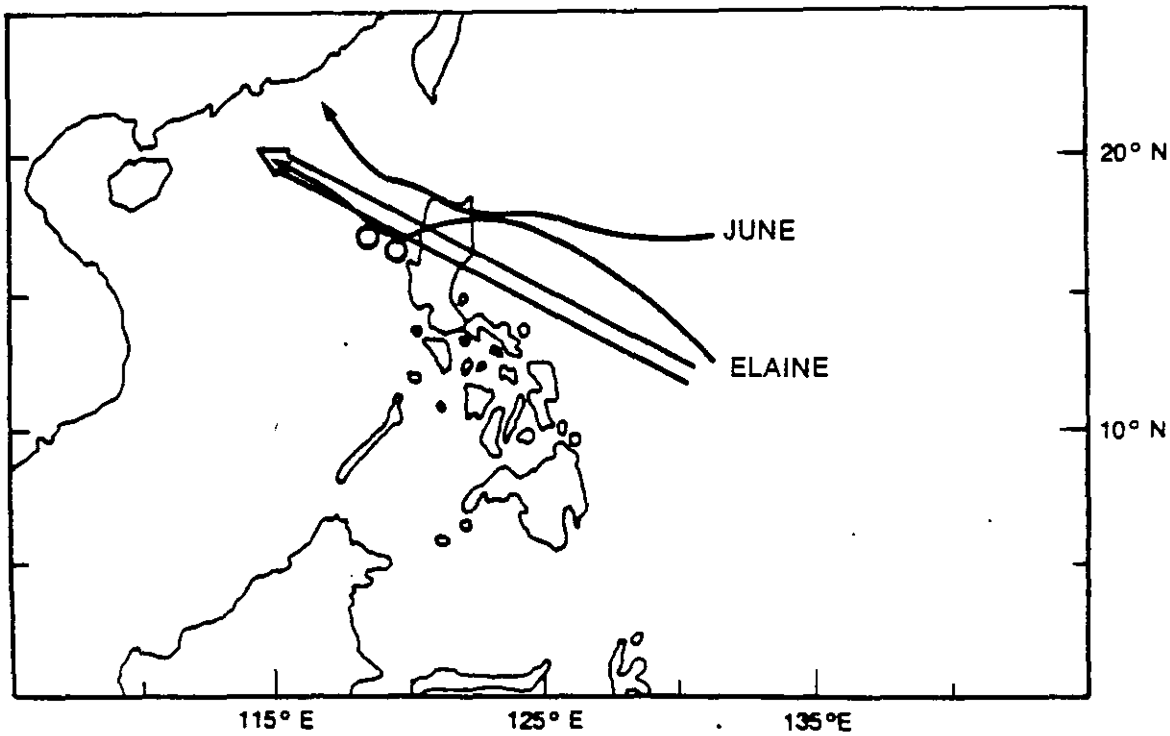

Figure 3c.--Track summary charts showing the storm track trend (wide line arrow) and selected typhoons and tropical storm tracks (narrow line arrow). August.

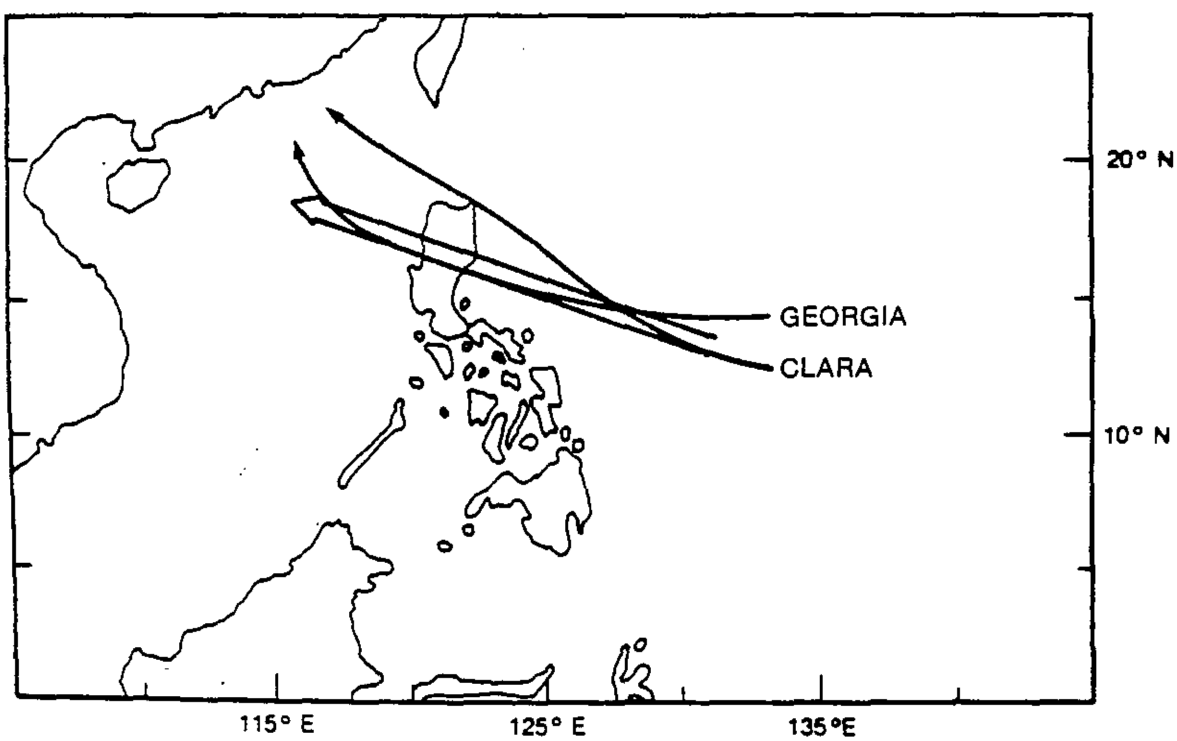

Figure 3d.--Track summary charts showing the storm track trend (wide line arrow) and selected typhoons and tropical storm tracks (narrow line arrow). September.

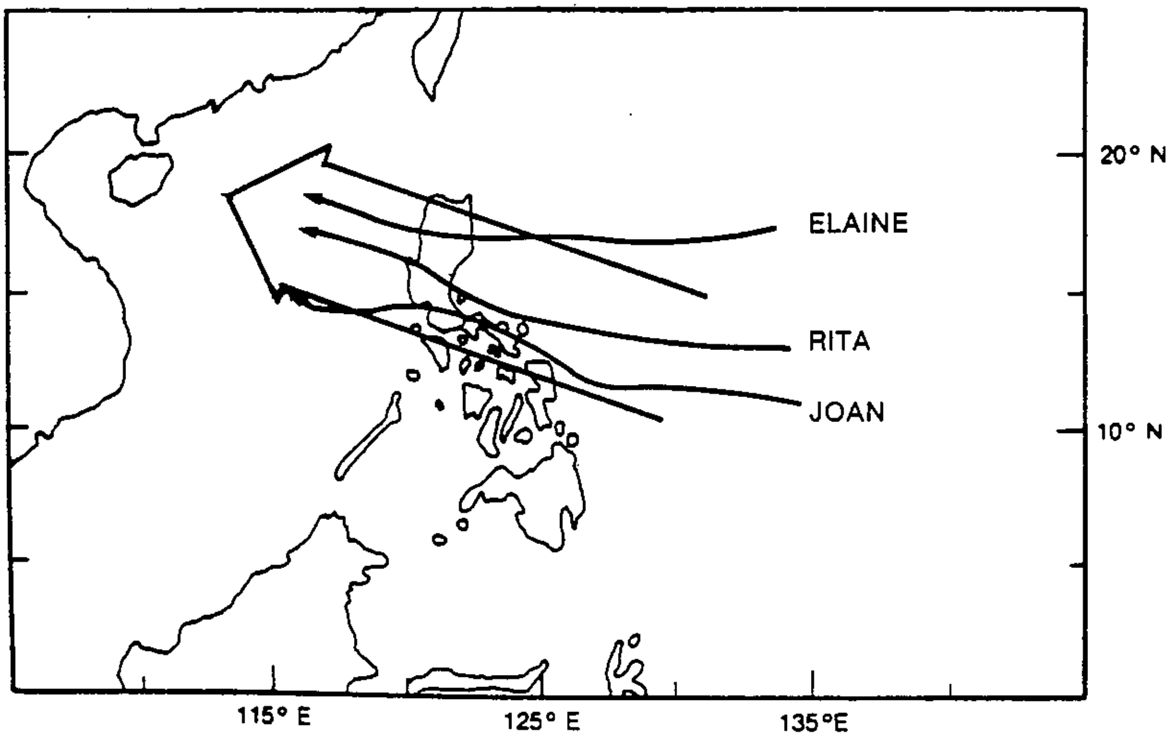

Figure 3e.--Track summary charts showing the storm track trend (wide line arrow) and selected typhoons and tropical storm tracks (narrow line arrow). October.

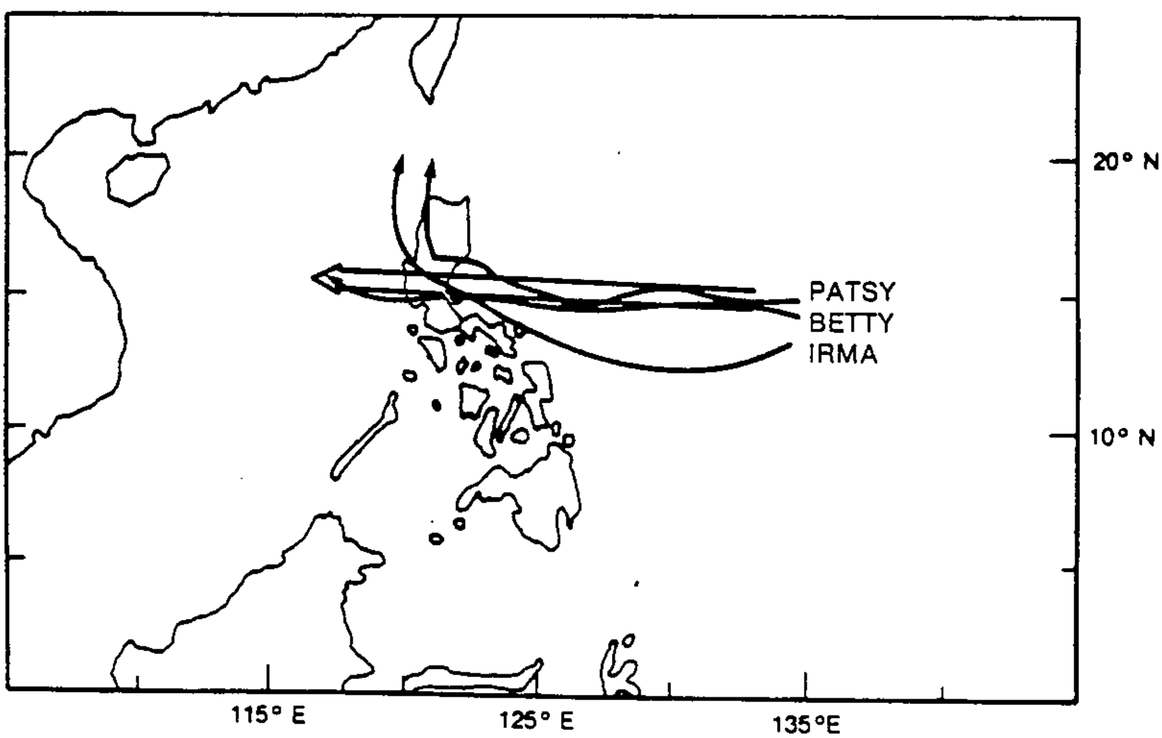

Figure 3f.--Track summary charts showing the storm track trend (wide line arrow) and selected typhoons and tropical storm tracks (narrow line arrow). November.

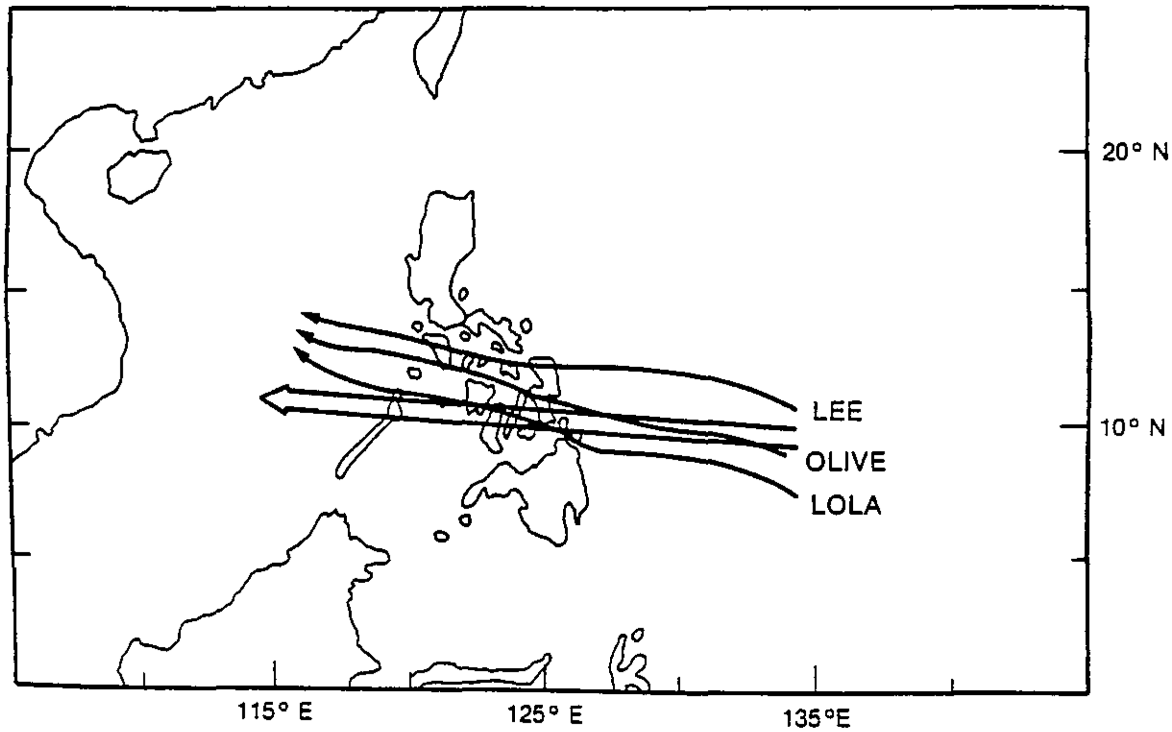

Figure 3g.--Track summary charts showing the storm track trend (wide line arrow) and selected typhoons and tropical storm tracks (narrow line arrow). December through May.

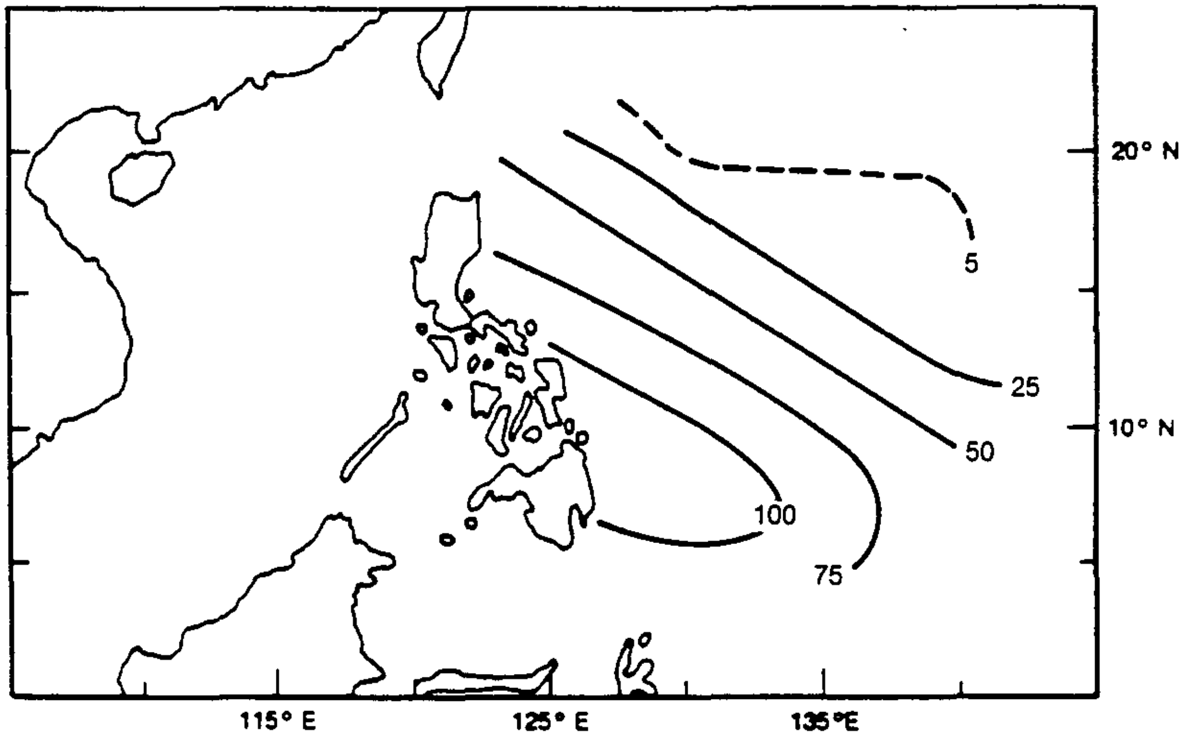

Figure 4a.--Probability of tropical cyclone crossing the Philippine Islands. June.

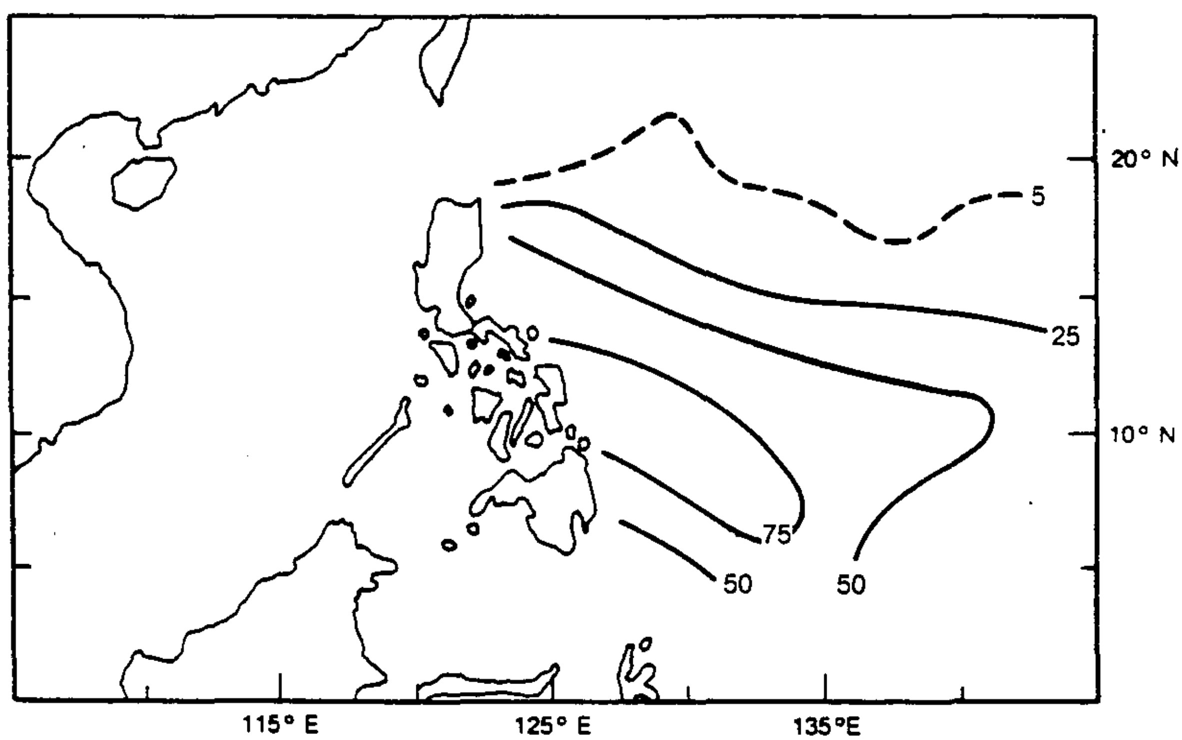

Figure 4b.--Probability of tropical cyclone crossing the Philippine Islands. July.

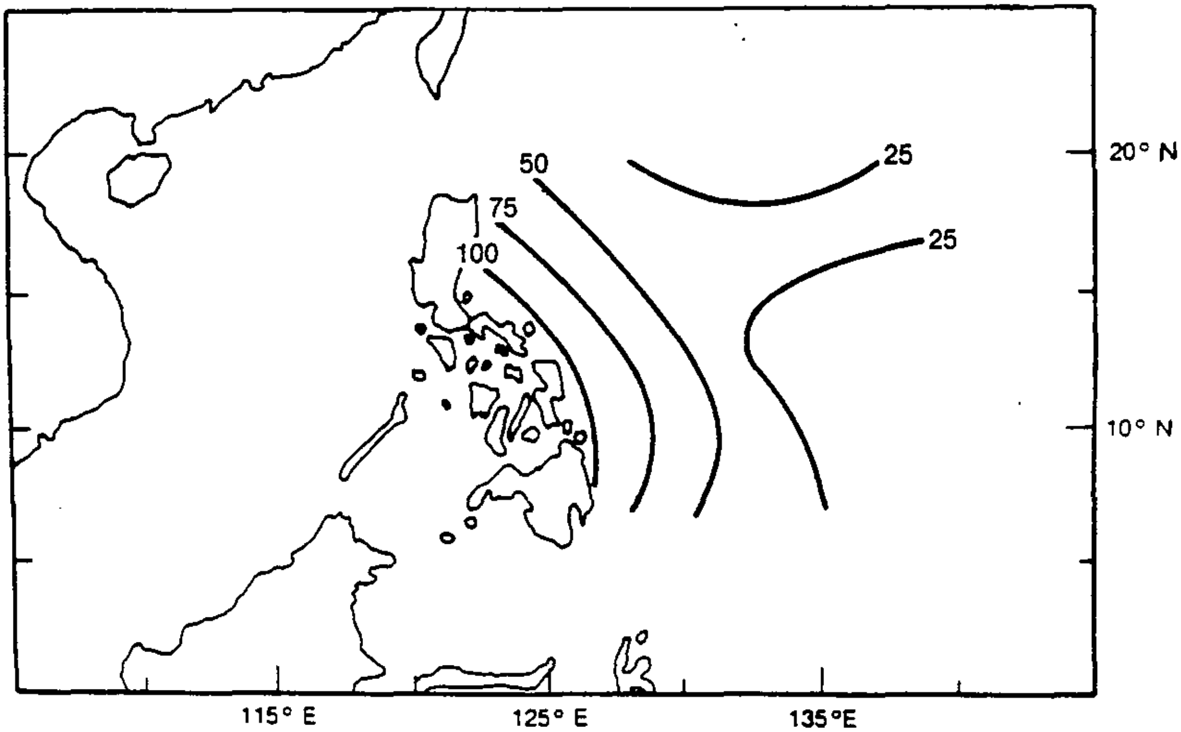

Figure 4c.--Probability of tropical cyclone crossing the Philippine Islands. August.

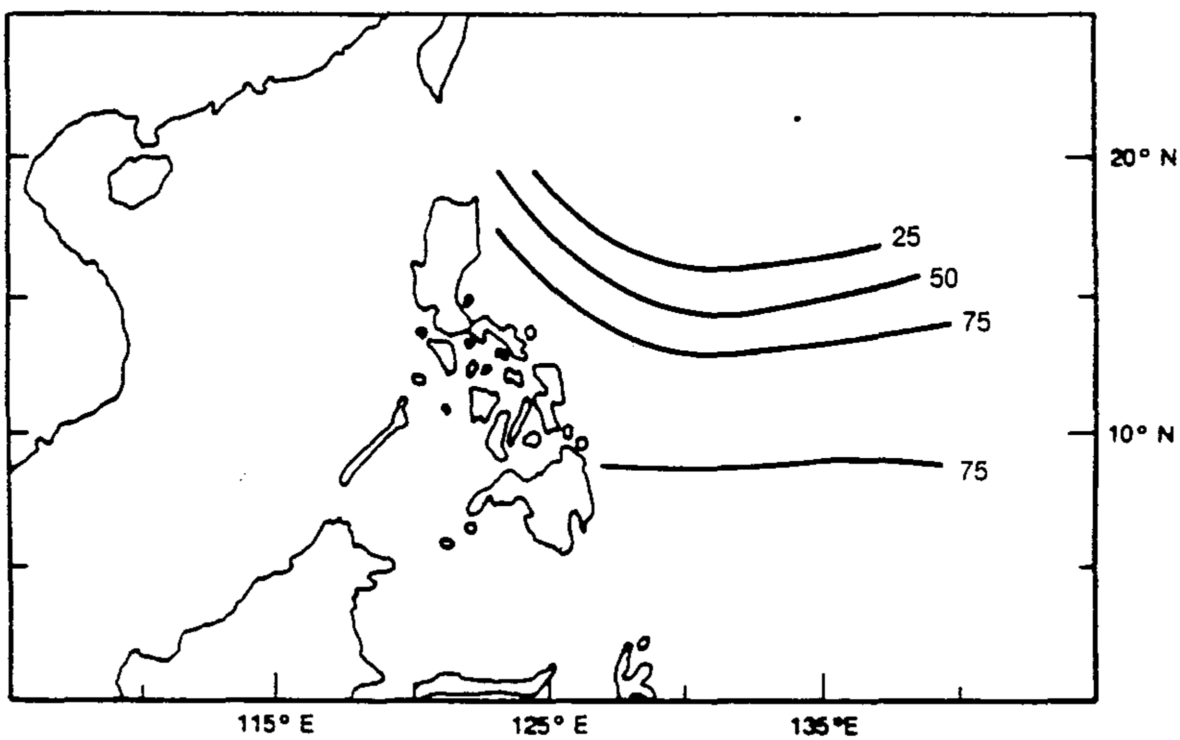

Figure 4d.--Probability of tropical cyclone crossing the Philippine Islands. September.

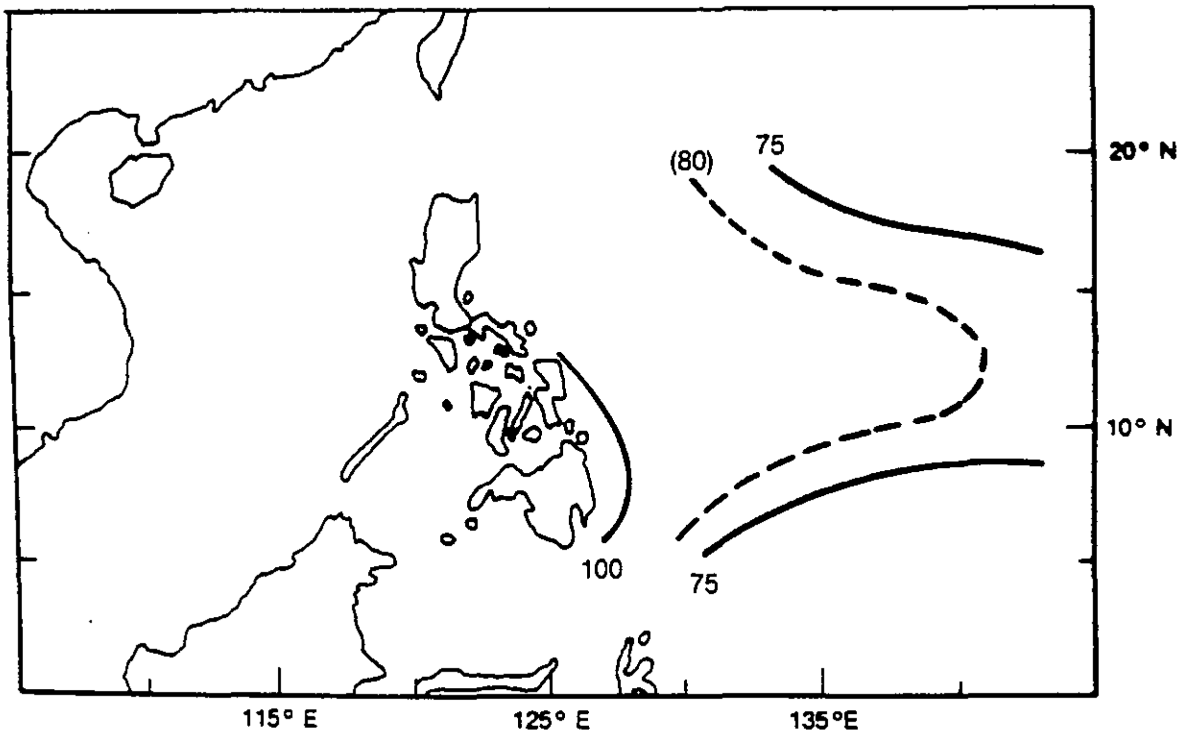

Figure 4e.--Probability of tropical cyclone crossing the Philippine Islands. October.

cyclone will track over the Philippines area for a given month if the storm is within a 5° latitude/longitude square. For example, if in June a storm center were located at 10°N, 130°E there would be a 100 percent chance that it would track over the Philippines. If it were at 12.5°N, 130°E there would be a 75 percent chance it would track over the Philippines. These charts were developed by calculating the percentage for each 5° square, for each month, of tracks crossing the Philippines compared to all tracks through that 5° square (for our 1970-1984 sample). This probability could be termed a "strike threat" (see Brand, 1976).

Much more could be done with this approach to determine a "threat" probability. A larger sample should be used to determine the percent frequencies. This means going back further in time, say from 1948-1984. The results will be more reliable and stable. A classification of cases based on surface weather conditions (positions of high or low pressure centers) and computations of percent frequencies based on the classification would give a useful forecast.

3. ECONOMIC ANALYSIS

In order to arrive at an adequate assessment of damages to the Philippines from tropical cyclones, it was necessary to 1) acquire data, 2) develop a framework for comparing the data from various storms including both economic and meteorological statistics, 3) develop a quick and reliable means for comparing these economic and meteorological parameters, and 4) develop an understanding of the relation of the damages from tropical cyclones to the economy of the Philippines.

The data sources were described in the Introduction and the selection of storms to be studied in Section 2. A third element necessary for an understanding of the methodology of this study is a description of the nature of the economic data and the types of analyses to be derived from them.

Economic data for assessment of damages is uneven and sometimes of question-able reliability. Unlike the meteorological data, the data used to estimate damages are not based on scientific observation and standard measurement. They are the product of personal observation and organizational measurement (i.e., the organization which does the measurement has its own methods and possibly its own biases). Therefore a research project using such observations must develop a framework which may assure the reliability of results.

In this study, the means for assuring reliability of results were: 1) the uses of ranges of values to accommodate varying assessment within specific damage categories and 2) the inclusion of observations from newspaper and journal material to supplement data on damages which have been observed by various organizations. Using these two tools, the investigator is able to make a judgment on damage amounts and yet have confidence that even if that judgment is somewhat imprecise, it will still fall within the given range.

The tool that was developed to rationalize this data and put it in a useful form for comparing with meteorological parameters is the Sheifer Index for Damage Evaluation. The concepts and methodological considerations in developing this index are described in Section 3.1 and the Damage Assessment Tables from which the index is drawn are contained in Appendix A. Subsection 3.1.3 gives the 15-year summary of tropical cyclone damage to the Philippines as evaluated by the index.

Another way of looking at the data on damages from tropical cyclones is to relate it to the Philippine economy on an annual basis. Therefore, annual summaries of amounts of tropical cyclone damage and brief accounts of the way in which this damage occurred were developed. The evaluations of this material are found in Section 3.2 and the summaries are in Appendix B.

3.1 Development of Sheifer Index for Damage Evaluation (SIDE)

To evaluate tropical cyclone damage and establish a possible means to predict damages from future events, it was decided to develop an index based on amounts of previous tropical cyclone damage. Such an index would be useful not only in giving an historical picture of loss but also in providing a method of assessing meteorological parameters in order to establish useful relations.

This was a two-step process. First data was arranged in tabular form and then the index was derived based on part of this tabulation.

3.1.1 Construction of Damage Assessment Tables

The Damage Assessment Tables have 19 types of information and contain both economic and meteorological data (tables by year appear in Appendix A). For the tropical cyclones selected (see Section 2.2), the data were assembled and entered into categories described below.

The identification of the storm was entered in columns 1 and 2 as follows:

1. Name of Tropical Cyclone and Type. Type designations are "TY" for typhoon and "TS" for tropical storm.

2. Day of Year (Julian). First date storm began impacting the Philippines (generally 12 to 36 hours before landfall).

The duration of the storm and the Philippine areas affected by it were placed in columns 3 and 4:

3. Length of Impact. Number of days from that impacts from the storm persisted.

4. Impact Zones. The Philippines were divided into the five major areas shown in Figure 5. These areas were selected on the basis of homogeneity of land/sea features and predominant form of industry/agriculture. If there was no reported area of impact, the designation "0" was used. If a storm impacted several areas, each area was designated. Impact areas are not, therefore, synonymous with the meteorological tracks.

Through an analysis of reports available, a judgment was made on major cause of economic damage to the Philippines and entered in column 5 in the following way:

5. Major Cause of Damage. Six categories were established as follows: "0" for none reported; "1" for wind; "2" for rain (frequently leading to flooding); "3" for storm surge; "4" for the combination of wind and rain; and "5" for a combination of major damage from wind/rain/storm surge.

Columns 6 through 11 constitute the major sources for the economic assessment in this study. The data were taken from published reports. In cases of conflicting estimates, a single figure was calculated based on all the data. As discussed above, the use of ranges of values into which to enter the data made the use of such estimates more reliable. The data are entered as follows:

6. Deaths. Four categories were established based on the highest number of reported deaths. "Missing" were not included in this category. The ranges are: "0" for none reported; "1" for under 100 deaths; "2" for 100-300 deaths; and "3" for above 300 deaths.

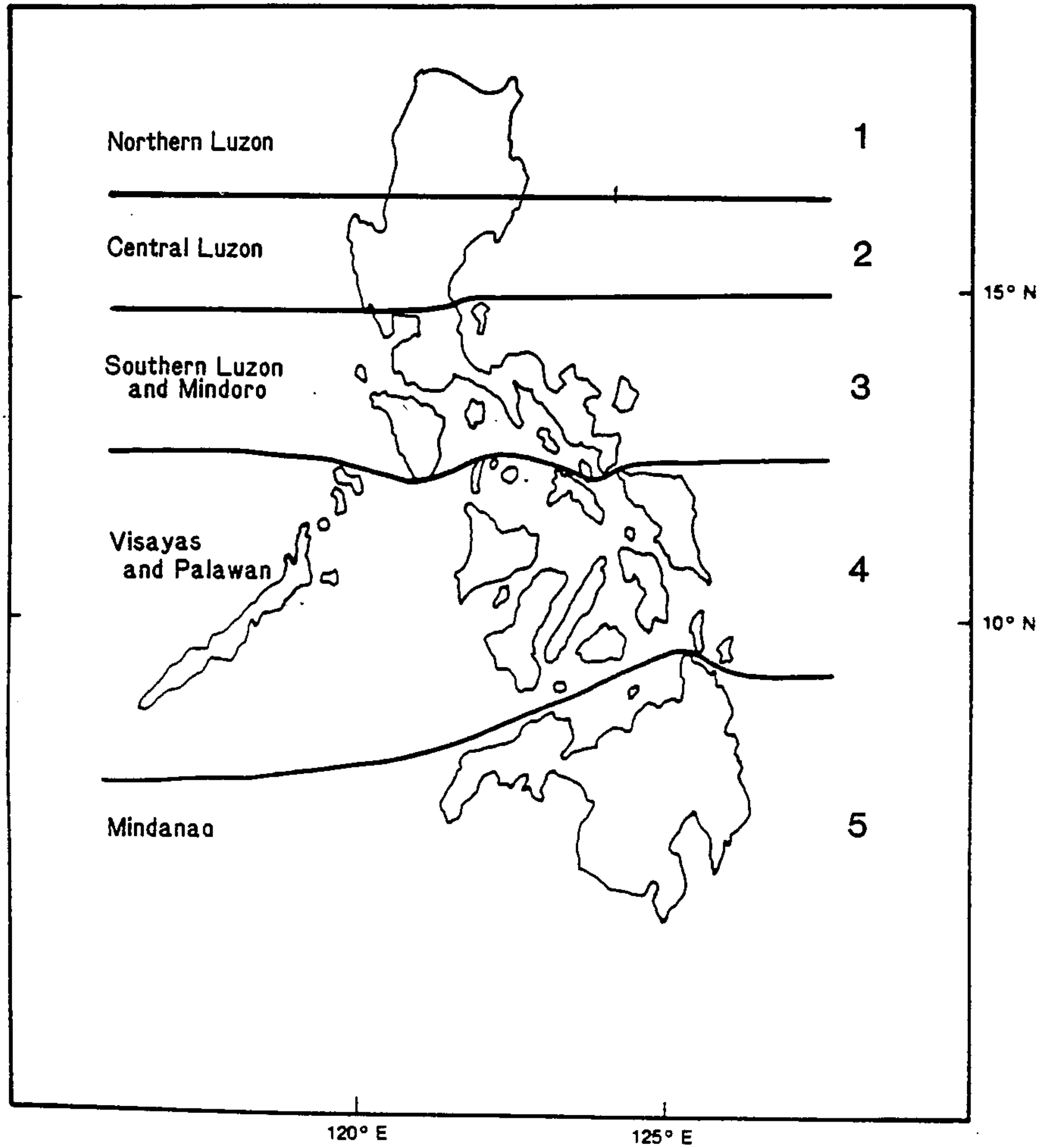

Figure 5.--Philippine damage impact zones.

7. Numbers Affected. Four categories giving the number of people affected by the tropical cyclone were defined: "0" for none reported; "1" for under 1000; "2" for 1000-100,000; "3" for 100,000-1,000,000; and "4" for over 1,000,000.

8. Boat/Ship Damage. Classification of damage was made by the kinds of vessels impacted by the storm. "0" is used for no reported damage; "1" indicates that only small craft were damaged; "2" indicates that both small craft and large ships were damaged.

9. Crop Damage. Ranges of damage were delineated as follows for damages to all crops (tree and field): "0" for none reported; "1" for less than $1 million; "2" for $1 million to $5 million; and "3" for damages to crops above $5 million.

10. Public Works/Infrastructure Damage. Six categories of damages were established in order to account for the large amounts of these damages and to be able to establish accurate ranges in order to evaluate them. "0" was established for none reported; "1" for damages of less than $1 million; "2" for $1 million to $5 million; "3" for $5 million to $10 million; "4" for damages of $10 million to $50 million; and "5" for those over $50 million.

11. Total Damages. The sum of estimated dollar damage from a given typhoon/tropical storm (Crop Damage plus Public Works/Infrastructure Damage) was categorized as follows: "0" for none reported; "1" for damages up to $5 million; "2" for $5 million to $50 million; "3" for $50 million to $100 million; and "4" for over $100 million. All dollar damages were assessed in terms of dollars at the time of damage. For an explanation of this methodology, see Subsection 3.1.2.

A method for providing an overall understanding of the intensity of impacts from a given tropical cyclone was needed. This overall rating was established in column 12 as follows:

12. Damage Classification Rating. Each storm was assigned a rating based on adding the figures assigned under "Deaths," "Numbers Affected," and "Total Damages." The range of values thus became 0-11. An explanation of the selection of these parameters appears in Subsection 3.1.2.

Meteorological data was entered in columns 13 to 18 as follows:

13. Wind Speed -24. Wind speed 24 hours before landfall in knots.

14. Wind Speed -12. Wind speed 12 hours before landfall in knots.

15. Max. Wind. Maximum observed wind speed in knots.

16. Min. SLP. Minimum sea level pressure in millibars.

17. Angle of Impact. Computed on basis of direction from which storm tracks (reference is north and 90° is east). "1" and "2" have no cases; "3" is for 195°-225° and 15°-45°; "4" is for 165°-195° and 45°-75°; "5" is for 135°-165° and 75°-105°; and "6" denotes 105°-135°.

18. Max. Rainfall. Two types of data are contained under this heading. The first subcolumn is maximum point rainfall in millimeters; the second is the World Meteorological Organization (WMO) observation station number.

While the overall damage classification rating is a useful tool, an abbreviated rating was necessary to combine these ratings into groupings that would be valuable for assessment purposes. This was entered into column 19 as follows:

19. Damage Evaluation Index (SIDE). The index numbers are from 1 to 5. An explanation of how these are assigned appears in the next section.

3.1.2 Construction of the Index

One of the first questions that needed to be resolved was whether the index should be country-specific or whether it should attempt to be universally applicable. Consideration of this point led to the conclusion that since there were many differences between the Philippines (a developing nation) and developed nations that a universal index was not feasible. The differences between the two types of nations' vulnerability to tropical cyclone damage and their responses to the impacts from these cyclones are numerous. The index that has been developed while applicable specifically to the Philippines is useful as a model for evaluation of damages in the developing nations of the Pacific and the Caribbean.

The items used for evaluation in the index needed to relate specifically to the most important elements of loss in the nation involved. For this study of the Philippines, three areas of loss seemed particularly applicable: deaths, numbers of people affected, and total dollar damages.

In a developing nation, deaths from a tropical cyclone are likely to be higher than in a developed one. More people are out of touch with warning systems in a developing nation, escape means are not always available, populations may be settled in areas subject to the most severe damage (for example, next to river beds which might become flooded), structures may be flimsy, roads may be nonexistent or destroyed leaving damaged areas inaccessible, and storm surge in populated low-lying islands may be devastating. Therefore, the number of deaths from a tropical cyclone is a significant indicator of loss from the storm.

In the same way, a measurement of the numbers of people affected adversely by the tropical storm is an indicator of the severity of the storm. Homes are demolished, roads and bridges washed away, towns buried under mud, fishing boats destroyed, water service cut off for prolonged periods, food supplies destroyed, etc. In a developing nation, where large numbers of people may be impacted by a storm, as in the Philippines, the economic loss from disrupted incomes and lives is great. In the Philippines, the tracks of some tropical cyclones are such that a major portion of the population is affected.

Total damages (in year-of-occurrence dollars) is obviously a critical indicator of loss. In this study, this figure combines the two separate categories of economic loss--that to crops and that to public works/infrastructure. At times in the Philippines, these losses have been staggering.

A major methodological consideration arose over the question of whether or not to make an inflation adjustment to dollar damage figures over the 15 year span of this study. It was decided not to make this adjustment in this pilot stage of the study for two reasons. First, the classification categories are broad enough to absorb some of this adjustment. Secondly, some of the dollar loss figures are based on sketchy estimates thus adding an inflation multiplier to them might lead to misleading interpretations. However, it should be noted that all peso figures were converted to dollar figures for the year involved according to tables published by the World Bank (Appendix C). As will be shown in the discussion which follows, the dollar damage figure comprises only about a third of the classification rating and this is further compressed in the construction of the index. Thus an inflation adjustment would not significantly change the findings of this study. There would be a minor number of changes in rank upward.

As a first step in constructing an index, each of the tropical cyclones in this study was evaluated in the three selected categories (deaths, numbers affected, and total damages). Ranges were established in each of the categories (see Subsection 3.1.1) and a number assigned. The maximum value in deaths was 3; in numbers of people affected it was 4; and in total damages it was 4. The maximum classification rating a storm could receive under this system therefore was 11. The structure of this rating is such that it is weighted toward the people (human suffering) side of the scale. This relates particularly to developing nations and it is believed this is a good test of a storm's severity in these nations.

The Sheifer Index for Damage Evaluation (SIDE) used in this study utilizes the classification ratings. These ratings are related to five index numbers on the following basis:

Index No.	Classification Rating Score	Characterization
1	0	Little or none
2	1-3	Moderate
3	4-5	Substantial
4	6-8	High
5	9-11	Very high

These index numbers were assigned on an evaluative basis using an historical analysis of storm damage. For example, those tropical cyclones with classification ratings of 4 and 5 historically seemed to be those associated with damages that could be characterized as substantial.

3.1.3 15-Year Summary of Tropical Cyclone Damage Using SIDE

Table 1 shows a summary of the distribution of tropical cyclone damage using the SIDE for the 128 storms evaluated in this study. Nearly 39.8 percent were categorized as having little damage or "none reported"; 22.7 percent had moderate damages; and 37.5 percent had substantial to very high damages.

3.2 Discussion of Annual Summaries

For each year from 1970-1984 a summary of the damage caused by the year's major storms is included (see Appendix B). The summary highlights types of

Table 1.--Sheifer Index for Damage Evaluation (SIDE) for selected tropical cyclones impacting the Philippines, 1970-1984.

Year	No. of Tropical Cyclones Evaluated	Rank				
		1	2	3	4	5
1970	9	3	2	1	1	2
1971	16	9	7	0	0	0
1972	12	7	1	0	3	1
1973	7	4	2	2	0	0
1974	11	4	2	4	1	0
1975	2	1	0	0	1	0
1976	5	1	1	1	1	1
1977	7	2	3	1	1	0
1978	8	3	0	4	0	1
1979	9	4	0	4	1	0
1980	8	2	4	1	0	1
1981	7	1	1	2	3	0
1982	9	1	2	4	2	0
1983	10	6	2	1	1	0
1984	7	3	2	0	0	2
Totals	128	51	29	25	15	8

damages in major categories and their impacts on the Philippine economy. A total of all damage for the year caused by tropical cyclones is included in order to show the overall impact of these storms.

3.2.1 Analysis of Types of Damage

The greatest losses that are experienced from tropical cyclones are in the area of human suffering. No dollar figures can be placed on these losses. Death, injury, starvation, disease, squalor, loss of habitable shelter, and the like are part of the tropical cyclone damage picture. While SIDE has identified these areas in order to evaluate the overall damage from these storms, the annual summaries emphasize monetary losses. These areas of loss are:

Crops. In regard to assessing crop damage, it is necessary to distinguish between damages to crops that are basically food crops and those which are export crops that produce foreign exchange income for the nation. The tracks of typhoons and tropical storms are very instructive in assessing these damages. In very broad terms, storms which damage Central Luzon and the Bicol region in a major way take their toll in rice and corn. Rice is the mainstay of the Philippine diet. Storms which track through the Visayas generally impact export tree crops (coconuts, pineapple, and bananas) and sugar. Tropical cyclones which strike Mindanao (generally northern Mindanao) also frequently damage the coconut crop. The Philippines has been a leading world supplier of palm oil (approximately 70 percent) which is derived from coconuts. Damage to tree crops will usually come from winds rather than rains.

Boats and Shipping. A category of damage, for which separate dollar estimates are not usually made, is damage to fishing boats, fish resources, and shipping. These damages are associated with heavy winds and storm surge. They are included in overall damages but not identified as a separate category.

Public Works/Infrastructure. By far the largest economic category is damage to property. In this assessment, the major type of property damage reported is damage to public property--schools, buildings, bridges, sewers, electricity, telephones, etc. This is done for three major reasons: 1) it is difficult to assess damage to homes, which are frequently rebuilt quickly; 2) damage to industrial property is sometimes less extensive because the quality of construction is better; and 3) damage to public property is significant matter for the Philippine economy. As we shall see, in any one year the total amount of damage to public property/infrastructure may be over $100 million.

3.2.2 Variability in Annual Damages

Damages from tropical cyclones vary in as many unusual ways as the storms they result from. For example, damage on an annual basis is extremely uneven. In 1971 the Philippines was struck by several insignificant storms which resulted in total damages of under $5 million. However, in both 1970 and 1972 a moderate number of storms in each year brought about damages of $186.6 million and $273 million, respectively. Another unusual aspect of storm damage assessment is that a storm of low intensity can bring about major damage. Susan in 1972 caused millions of dollars of damages even though she never was stronger than a tropical depression while crossing the Philippines.

Damages in different categories of loss also vary from year to year and it may take only one storm to bring about heavy loss. For example, TY Lola caused over $156 million of damages in 1975 by damaging the sugar crop. In 1976 TY Olga caused considerable damage to public works by meandering across Luzon with heavy rains. Flooding and mudslides caused havoc in the affected areas.

The pattern of storm tracks also vary from year to year and this too has an impact on yearly damages. In 1974, 9 of the 11 storms affecting the Philippines tracked across Luzon. Damages were compounded as storms struck areas already damaged or flooded. In other years, the pattern of tracks is such that damage is widely dispersed and may be very serious. In 1984, damage statistics were heavily influenced by losses resulting from one of the most damaging storms of the century, TY Ike. However, TY Agnes and TS June caused damage to sugar and rice, respectively.

Three tropical cyclones have been selected for brief presentation of their meteorology and their damages to illustrate some of the points just discussed. They are TY Susan (1972), TY Lola (1975), and TY Ike (1984).

TY Susan, 1972 (see Figure 6a). Wind speed and damage are frequently related, but in Susan's case this was not so. Never attaining a maximum wind speed of 34 knots while crossing the Philippines, Susan's damages came from her influence on monsoonal flows. Susan was the first of the many tropical cyclones developing in the equatorial trough in July 1972 and was detected on the 4th. Between July 5 and July 7 TY Susan moved across the Eastern Visayas, through the Bicol Peninsula and Southern and Central Luzon, and emerged in the region of the Lingayen Gulf. Following an erratic course into the South China Sea, she became stalled there on the 9th. Meantime TY Rita, which did not track across the Philippines, was meandering in the central Philippine Sea. The circulations of these tropical cyclones intensified the southwest monsoon over the northern Philippines. Inundation from high tides and large waves occurred along the western coast of Luzon. In Manila, some sections of the seawall were ripped by wave action. Heavy rains brought disastrous floods in many provinces of Central Luzon during the several weeks the strong flow persisted. TY Ora had preceded TY Susan and rain fell in Central Luzon from late June until early August, a period of over 40 days. Total damages to the Philippine economy as a result of this low-wind-speed storm were over $225 million in 1972 dollars and in terms of monetary loss Susan is the most significant storm in this study.

TY Lola, 1975 (see Figure 6b). Lola was an unusual late-January storm (the ninth January storm since 1945) and one of the most destructive during the period 1970-84. She also illustrates the importance of season to damage from tropical cyclones. From its origin in the monsoon trough in mid-January, Lola tracked west-northwest developing minimal typhoon strength late on the 23rd and striking the central Philippines sugar-producing region on the 23rd and 24th. At least 30 persons were reported killed by landslides and flying debris and more than 300 houses in the coastal town of Tandog were destroyed by the storm. Sugar is harvested from October through April in the Philippines. Crops were so severely damaged by Lola that the Philippine government banned the export of sugar until mid-February. Total exports of centrifugal sugar declined from 1,542,000 metric tons in 1974 to 972,000 metric tons in 1975, a net loss to the Philippine economy of $156 million.

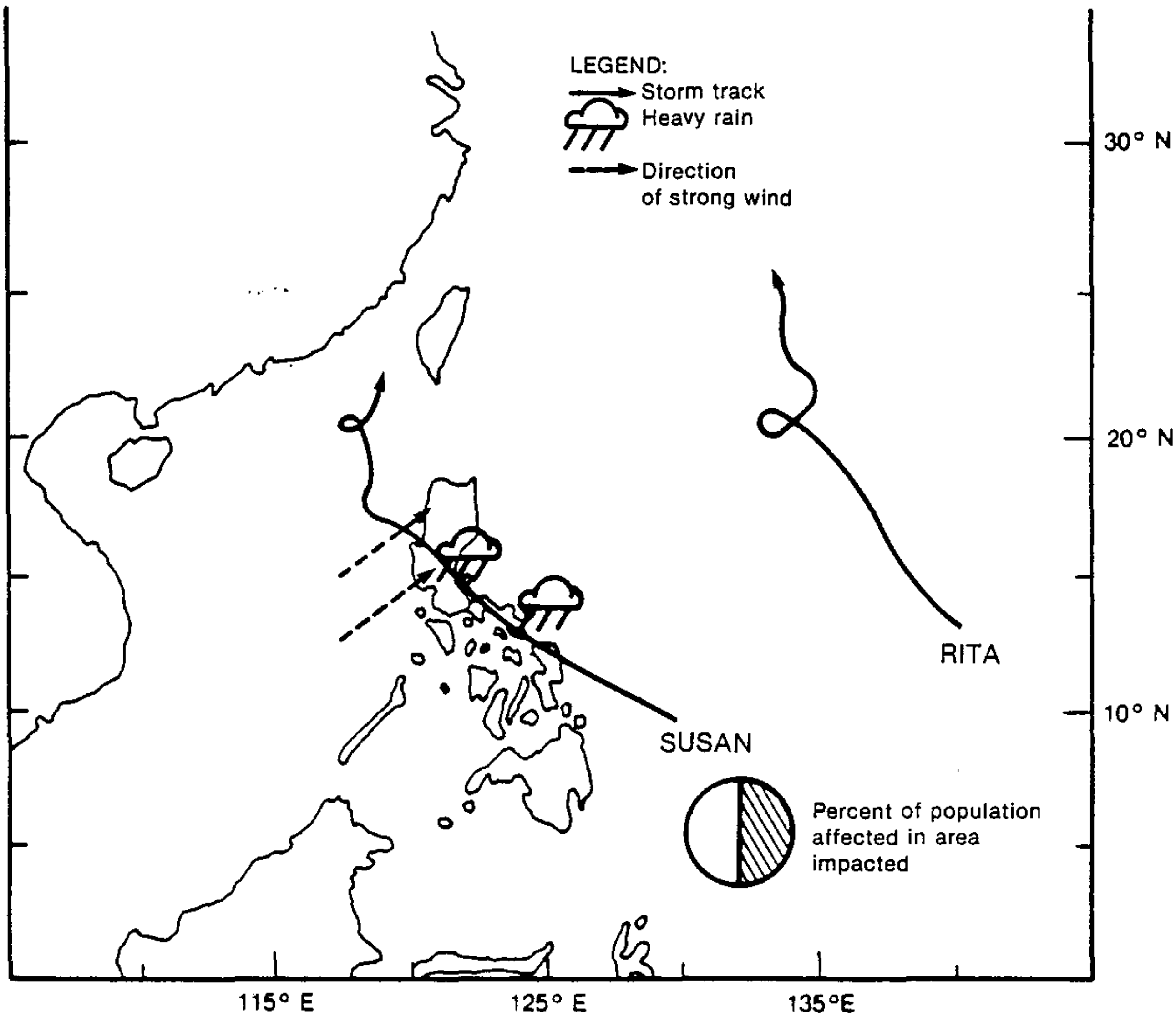

Figure 6a.--Depiction of selected storm tracks and their effects. Susan (and Rita) July 1972.

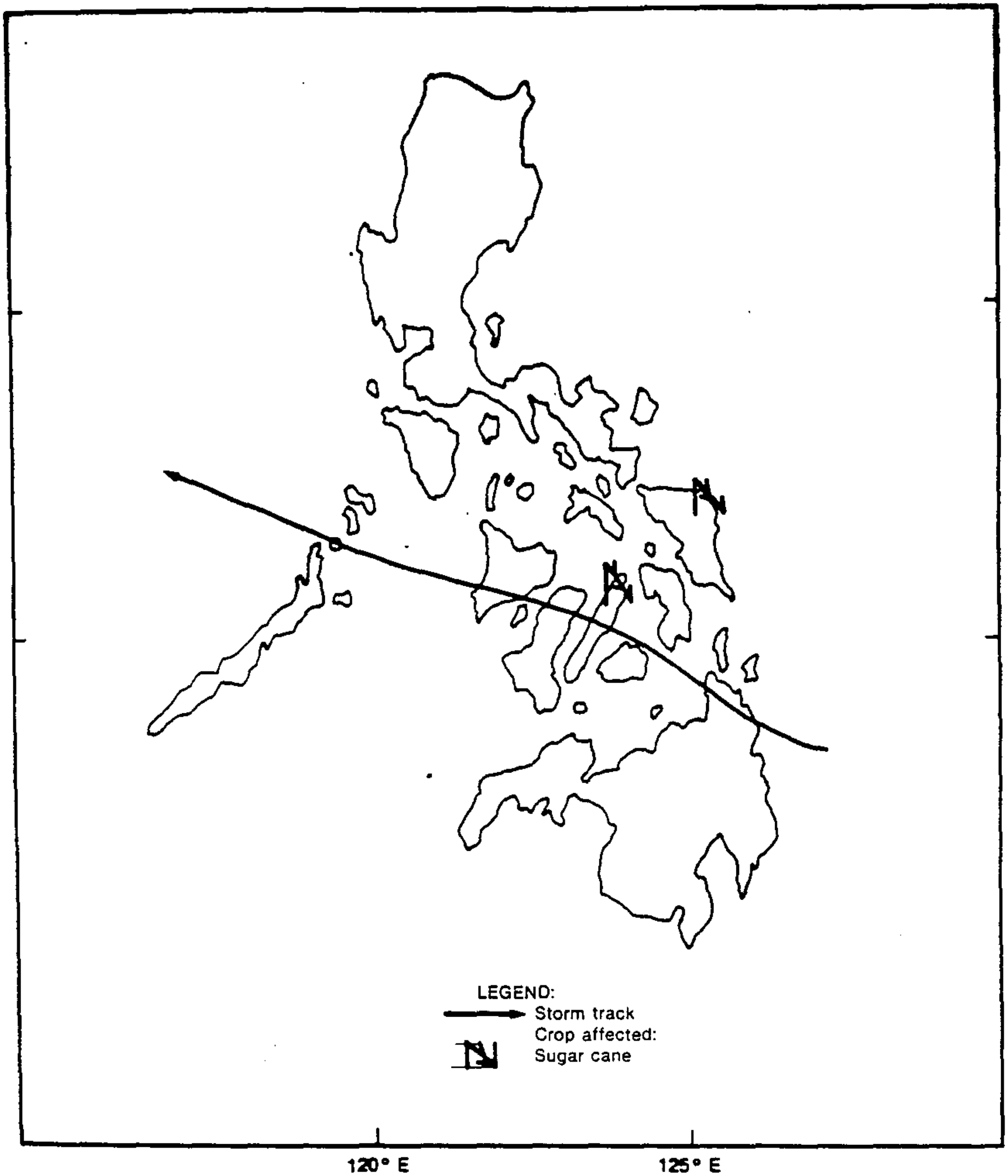

Figure 6b.--Depiction of selected storm tracks and their effects. Lola January 1975.

TY Ike, 1984 (see Figure 6c). The deadliest typhoon to strike the Philippines in this century began as a weak disturbance on the eastern end of the monsoon trough. After passing Guam as a developing tropical storm, Ike turned to the west-southwest and gradually intensified. Ike attained a maximum surface wind speed of 125 knots and struck the northernmost tip of Mindanao on September 1. This area is one not normally struck by typhoons, particularly one of this intensity, and the area was not particularly prepared for the ordeal caused by Ike. Ike continued its destructive course through Bohol, Cebu, and Negros, with winds weakening somewhat, and then turned northwestward moving through the Sulu Sea and striking the Calamian Islands. The hardest hit province was Surigao del Norte in northern Mindanao where over 1,000 people died. The number of people left homeless was over 300,000 and, overall, the storm adversely affected over a million people. Over 90 percent of the coconut trees in Surigao del Norte were destroyed and the sugar crop in Cebu and Negros was damaged. Throughout the region, pineapples and bananas also sustained considerable damage. Destruction of homes and other property was staggering as rain-caused floods and mudslides added to the damage from winds. Over $125 million of damages were attributed to Ike. This alone would have been significant enough to cause problems for the Philippine economy, but, additionally, two other storms during the year brought the damage total to $221.8 million.

3.2.3 Factors Affecting Amounts of Damage

An analysis of the damages caused by typhoons and tropical storms which impact the Philippines reveals that several major variables are involved. These are:

(1) wind speed of the storm as it passes through major areas (that wind speed varies as the storm moves),

(2) amount of rainfall in a given locality,

(3) previous rainfall in that area from other storms that has created flooding or the potential for flooding,

(4) interaction of tropical cyclones and monsoonal flows which may lead to prolonged periods of rain,

(5) advance preparations for the storm,

(6) historical frequency of typhoons in the area--localities with no history of typhoons are usually harder hit by typhoons that do strike,

(7) season: crops in different seasons are in different stages of development and therefore more susceptible to damage at certain times of the year, and

(8) population density in impacted areas.

3.2.4 Relative Significance of Export Crop Losses and Public Works Losses

Over the years 1970-1984 recurring damages to public property and the constant need to rebuild what has been destroyed have been a major economic problem

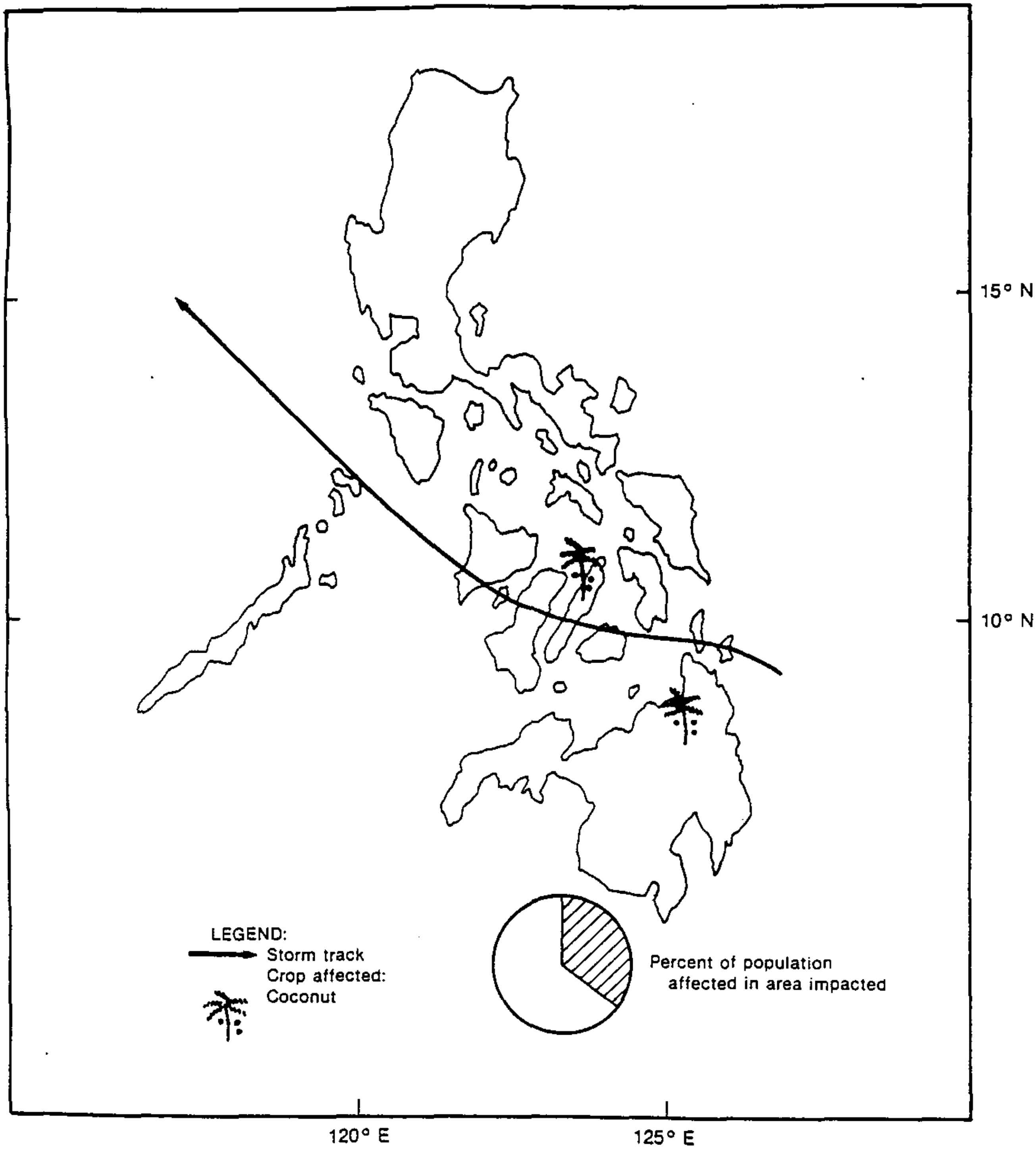

Figure 6c.--Depiction of selected storm tracks and their effects. Ike September 1984.

for the Philippine government but one that has not been given major scrutiny. The major share of attention has usually gone to damage to crops for the export market.

A single example of the kinds of problems the Philippine economy faces from typhoon damage is instructive. Around May 20, 1976, TY Olga began impacting the Philippines, particularly with rain. A dike broke in Pampanga Province 60 miles north of Manila. Other dikes were reported breached and 13 bridges destroyed in the provinces of Pangasinan, Nueva Ecija, and Tarlac. Sixty heavily populated communities were inundated and flooding left 630,000 homeless. The Philippine government had invested heavily in the region developing irrigation networks, highways, and feeder roads. The government estimated losses at $66 million.

Highlighting the significance of tropical cyclone damage to public works/ infrastructure and the problems of the Philippine economy is particularly necessary owing to the changing structure of the country's foreign exchange income. Older surveys have tended to emphasize damage to crops from typhoons as the major item of significance to the Philippine economy. However, Table 2 shows that the growth of exchange income as a result of nontraditional manufactures in recent years has far outweighed the significance of export crops to the Philippine credit balance. In 1981, for example, the total f.o.b. value in millions of U.S. dollars (at current prices) for coconut products, sugar and sugar products, and fruits and vegetables was 1,384. The comparable figure for non-traditional manufactures was 2,609.

Given today's international market in agricultural products, crops may be more affected by international supply and demand or restrictions on market forces than by potential damage from typhoons. This would be true both for sugar and for coconuts and the products derived from them. For example, the outlook for sugar, long a foreign exchange earner of the Philippines, indicates that should a typhoon inflict damage on the Philippine crop, overall monetary damage to Philippine economy would not be as great as previously since world sugar prices are already depressed by large supplies. A comparable amount of damage to public works in the Philippines would cause substantial drain on public resources further detracting from the opportunity for real economic growth.

Table 2.--Philippine Exports by Commodity Groups (f.o.b. value in millions of US$ at current prices)

Category	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Coconut Products	227	372	608	462	536	723	872	965	781	718
Copra	110	166	140	172	150	201	136	83	47	34
Dessicated coconut	18	32	60	31	37	90	82	107	116	102
Copra meal or cake	16	23	28	33	54	58	69	86	81	81
Coconut oil (crude)	83	151	380	226	295	380	585	683	537	501
Sugar and Products	216	293	765	615	451	526	213	239	590	454
Centrifugal	209	274	737	581	427	506	197	212	557	416
Molasses	7	19	28	34	24	20	16	27	33	38
Forest Products	226	414	292	223	264	261	323	484	420	344
Mineral Products	240	423	519	365	431	520	534	820	1,168	954
Fruits and Vegetables	44	48	76	108	123	128	144	171	196	212
Pineapple canned	20	20	31	35	47	56	60	74	82	88
Bananas	24	28	45	73	76	72	84	97	114	124
Nontraditional Manufactures	96	252	343	410	574	772	1,076	1,520	2,108	2,609
Garments	2	58	94	107	185	250	326	404	500	618
Electrical equipment and components	2	11	27	47	84	124	253	412	671	838
Handicrafts	13	27	46	78	95	84	100	134	154	134
Food products and beverages	12	15	17	15	20	31	41	57	170	361
Other	67	141	159	163	189	283	356	513	613	658
Other Exports	57	84	122	111	195	215	263	402	525	431
Total	1,106	1,886	2,725	2,294	2,574	3,151	3,425	4,601	5,788	5,722

Source: World Bank, The Philippines, Selected Issues for the 1983-87 Plan Period (1982).

4. CORRELATION OF SIDE TO METEOROLOGICAL DATA

Figure 1 (p. 7) shows the monthly distribution of total storms, the number affecting the Philippines, and the number causing substantial, high, and very high damage. This figure will be a useful reference point in understanding the discussion that follows.

All data from the annual Damage Assessment Tables contained in Appendix A were entered into a relational database using Oracle software on the AISC VAX 11/750. This was accomplished by creating a data file on the VAX and then creating a relational table in Oracle (called DAMAGE). The data file was read into DAMAGE. The column headings from the Damage Assessment Tables thus became the attributes of the database and the data for the 128 tropical cyclones are the records. The data for Impact Zones was entered in a slightly different manner than on the annual tables. An attribute was designated for each impact zone (1-5) and a flag, "1," was placed under each attribute for which there was an impact. The database is contained in the single table. Several sorts of the records were performed on maximum observed wind speed, minimum sea-level pressure, and greatest observed rainfall for all stations; other sorts were performed on a sample of data for the 5 years from 1979 to 1983 for the number of stations with total storm rainfall > 100 mm, and wind speeds 12 and 24 hours before impact. Table 3 shows a sample of the sort on observed minimum sea-level pressure. "ST" is the meteorological classification of the storm, either "TY" for typhoon or "TS" for tropical storm; "NAM" contains the name of the storm; "YRS" gives a 2-digit designation of the year the storm occurred; "DAT" gives the Julian day for the first day of impact of the storm on the Philippines; "SID" has the index number derived by using the Sheifer Index for Damage Evaluation (SIDE); and "SLP" has the number for the minimum sea-level pressure of the storm.

4.1 SIDE as a Function of Maximum Wind Speed, Number of Stations with > 100 mm Rainfall, and Minimum Sea-Level Pressure

The maximum wind speed, minimum sea-level pressure, and number of stations with total storm rainfall > 100 mm gave the highest correlation to separate storm damage categories for the 1979-1983 data. A two-variable cluster analysis was developed on these variables and is shown in Figures 7a and 7b. These figures show that using either maximum wind speed and minimum sea-level pressure or maximum wind speed and number of stations with > 100 mm of rain provides a fairly good separation of damage categories. There are more "1" symbols in the lower portion of the figures and more "4" and "5" symbols in the upper portion. The lines in the figures separate the averaged values for the clusters. In both figures, it may be observed that for this 1979-83 sample approximately 50 percent of the storms fell into exactly the proper category and 83 percent were within one category, i.e., plus or minus one category from the proper one.

4.2 SIDE and Wind Speed at -12 Hours before Landfall

To see if there was predictive information in the wind data for 1970-84, we first sorted the data on wind speed at -24 hours before impact and wind speed at -12 hours before impact. The first did not prove useful. The sort on wind speed at -12 hours and SIDE index showed promising results. To delineate the damage cases we looked for a threshold value on which to stratify and found 60 kt

Table 3.--Sample of Sort Using Minimum Sea Level Pressure.

ST	NAM	YRS	DAT	SID	SLP
TS	MAMIE	72	121	1	
TY	CORA	72	225	1	
TY	ELSIE	72	243	1	
TY	LORNA	72	291	1	
TY	SALLY	72	334	1	
TS	THELMA	73	315	1	
TY	SARAH	83	172	1	
TY	ALEX	84	182	1	
TY	BETTY	84	185	1	
TY	BILL	84	319	1	
TS	SARAH	77	197	2	

ST	NAM	YRS	DAT	SID	SLP
TS	JUNE	84	241	2	
TY	WARREN	84	297	2	
TY	IKE	84	244	5	
TY	AGNES	84	308	5	
TY	KIM	71	190	1	380
TY	LUCY	71	189	2	926
TS	BABE	71	123	1	939
TY	IRMA	81	327	4	950
TY	LEE	81	358	4	951
TY	JOAN	70	284	5	951
TS	FAYE	74	304	1	955
TY	PATSY	70	321	5	955
TY	BETTY	80	308	5	956
TY	ELAINE	74	300	4	959

ST	NAM	YRS	DAT	SID	SLP
TY	NANCY	70	53	2	960
TY	OLIVE	78	109	3	962
TY	CLARA	81	261	4	962
TY	FAYE	71	281	1	966
TY	THELMA	77	203	2	967
TY	ORA	72	175	4	970
TY	VERA	79	308	3	971
TY	RUTH	73	287	2	972
TY	GLORIA	74	309	2	972
TS	GLORIA	71	282	2	973
TY	IVY	74	190	3	973
TY	RUBY	76	175	3	973
TY	CECIL	79	104	4	973
TS	RUTH	77	161	1	976

ST	NAM	YRS	DAT	SID	SLP
TS	DINAH	77	257	4	977
TY	KIM	77	316	4	977
TY	GEORGIA	70	251	3	978
TY	NORA	73	279	3	978
TY	DINAH	71	145	2	979

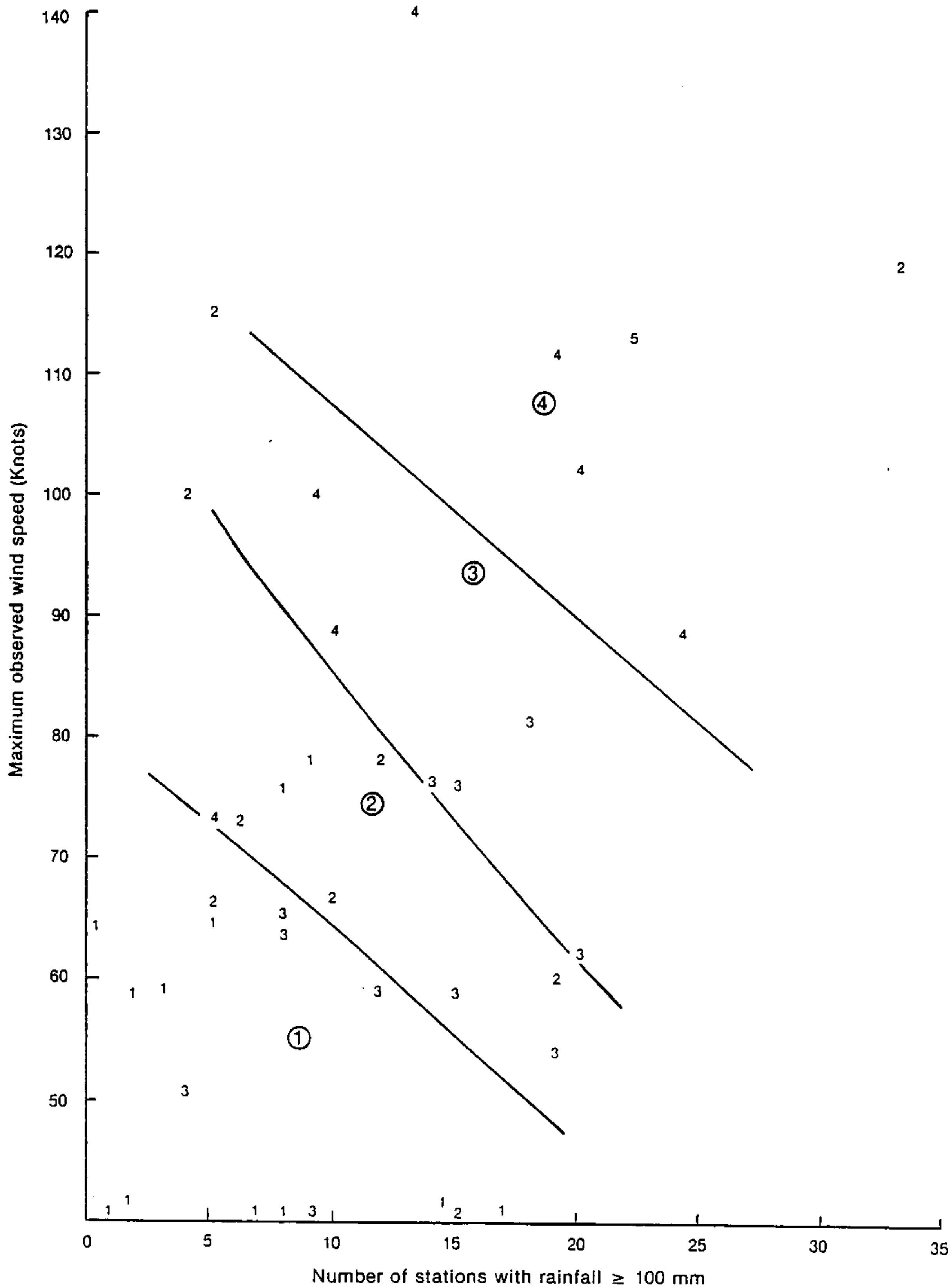

Figure 7a.--Sheifer index as a function of maximum wind speed and number of stations with $\geq$ 100 mm of rainfall.

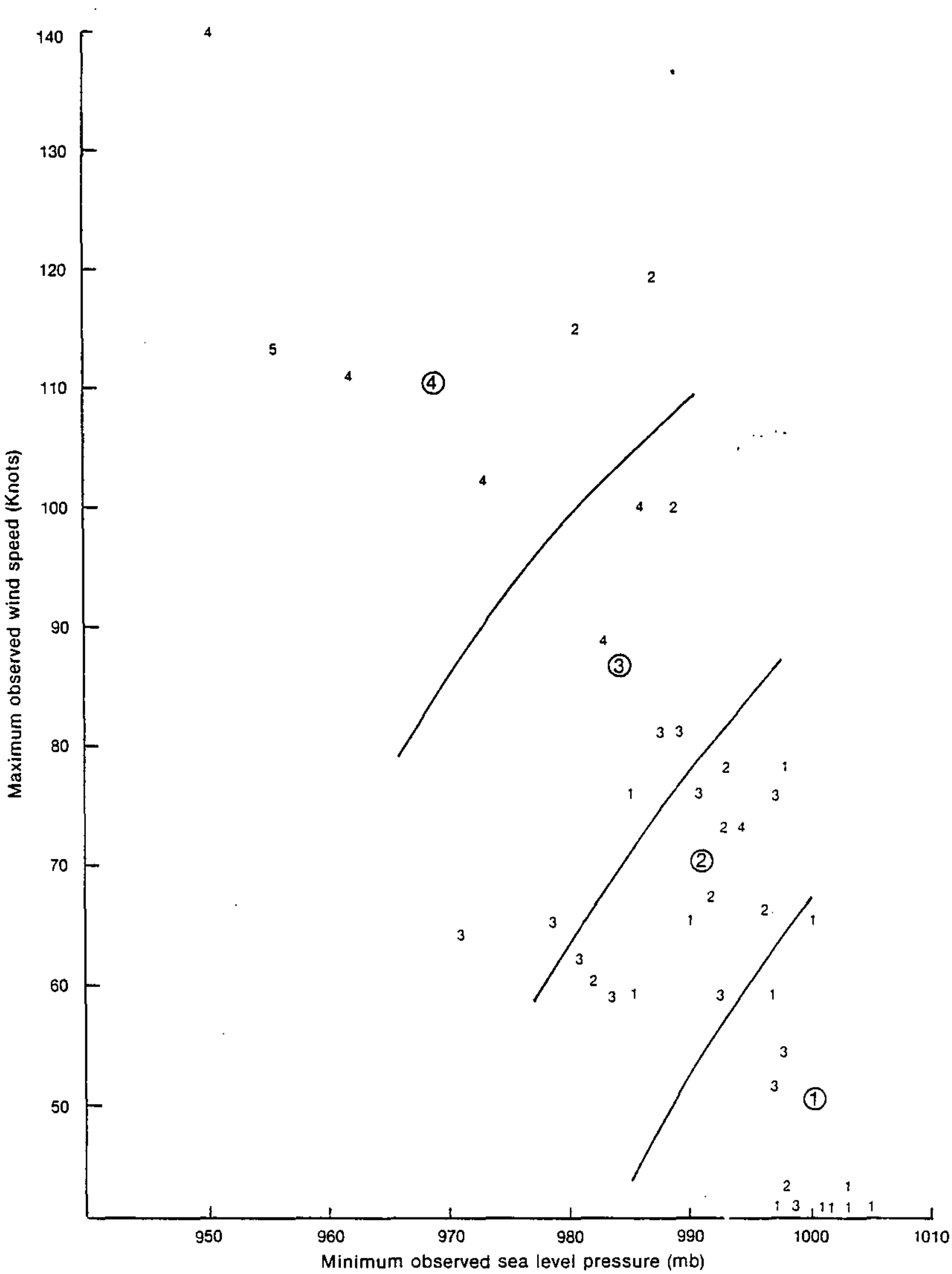

Figure 7b.--Sheifer index as a function of maximum wind speed and minimum sea level pressure.

seemed useful. This separated almost all the high and very high damage cases (SIDE values 4 and 5) and almost 50 percent of the substantial cases (SIDE value 3). The results of these sorts indicated that for the time period after July 1, when the wind speed 12 hours before impact was 60 knots or greater then 73 percent of the storms had damages which were substantial or greater (SIDE 3, 4, and 5). For the year beginning January 1, if the wind speed was less than 60 knots, only 25 percent of the storms had damages which were substantial or greater (SIDE values 3, 4, and 5).

5. SUMMARY AND RECOMMENDATIONS

Meteorological and economic data were collected, analyzed, and simple indicators were derived to assess typhoon damage. The physical variables of the storm needed to relate the damage are 1) intensity, 2) size, 3) rainfall, 4) storm surge, 5) duration, and 6) time of occurrence relative to previous storm. Item 6 is important up to a certain point, which is about two weeks. After that time, it is no longer a factor since the area is likely to have returned to "normal."

We analyzed typhoon reports from 1949 to 1984 from PAGASA and JTWC publications. These typhoon tracks and other storm characteristics were compared with earlier storm climatologies (1884-1948) in Gray (1970). We found that storm tracks in the Western Pacific during the last century are basically unchanged. We then concentrated on the later period, 1970-1984, because of availability of damage information.

For 1970-1984 we selected 128 out of 306 storms for this study. Based on the meteorology alone, these storms were tropical storms or typhoons; thus damage is strongly dependent on storm intensity. We devised descriptors of damages in a quantitative manner. From the sum of the descriptors, a simple damage index was developed--the Sheifer Index for Damage Evaluation (SIDE). The index range from 1 to 5 indicates none/slight to very high damage, respectively.

The economic consequences of tropical cyclones are far-reaching and particularly significant to a developing nation. Of the 128 storms studied, we found, using SIDE, that approximately 37.5 percent had substantial to very high damages. Although tropical cyclone damage was not significant in every year of the study, Table 4, below, which summarizes the results of our studies in Appendix B, shows

Table 4.--Yearly Summary of Dollar Damage from Tropical Cyclones, Philippines, 1970-1984.

Year	No. of Storms Evaluated	Total Estimated Dollar Damage (in Million $/Year of Damage)
1970	9	186.6
1971	16	5.0
1972	12	273.0
1973	7	17.0
1974	11	55.3
1975	2	160.0
1976	5	94.0
1977	7	65.7
1978	8	180.6
1979	9	55.2
1980	8	192.3
1981	7	164.4
1982	9	175.1
1983	10	71.4
1984	7	221.8

that in 13 of 15 years damages exceeded $50 million; that in 8 of these 13 years they exceeded $100 million; and that in 2 years they exceeded $200 million. Such sums are significant to developing economies. Damages to public works/ infrastructure are particularly important because there is an immediate need to rebuild which detracts from monies available for other development.

A second quite significant consequence of tropical cyclone damage is impacts on human beings, which we have categorized as "human suffering." Such suffering can be significant to the day-to-day functioning of a nation. Complex relationships are interrupted while a region or island attempts to cope with recovery. The wider the damage, the more serious the problem. Often as the recovery period is underway or is ending, another tropical cyclone strikes.

In our attempt to find a predictive method for damages, we have found the highest positive correlation between wind speed 12 hours before landfall of a cyclone (occurring Julian day 181 through 365) and substantial to very high damages. We hope to continue this research to see if we are able to establish other indicators. Positive results would be of help to national governments and international agencies in responding quickly to damage situations. Such information is also useful to others working in hazard mitigation and damage minimization efforts.

This is only a pilot study, and several avenues are open to expand and improve the approach and methodology. One very promising area is the use of remotely sensed data. Storm parameters can be measured and inferred from satellite measurements. These include size, intensity, maximum wind speed, and rainfall. By combining conventional and satellite data, we will understand more about these storms. Another application is to do assessments for other locations such as the Bay of Bengal. This is timely since Bangladesh recently acquired the state-of-the-art technology equipment for receiving and processing satellite data. A similar approach may be taken in the Caribbean area to unify the meteorological data with hurricane damage.

In the economic area in particular, a good deal of work needs to be done in the precise reporting of damages. The current situation is that very broad-brush estimates are made or none at all. Little information exists on storms with minor damages (those not involving international relief). Where damages are reported for severe storms, the data is not sufficiently detailed to make a qualified assessment of economic impact. A greater detail in reporting would help national and international agencies in deciding what actions need to be taken. It would also make the prediction of economic damage from tropical cyclones more accurate.

It is therefore suggested that the next phase of this study should address developing a standardized method for reporting damages from tropical cyclones in the Philippines. This project would be conducted by the Marine Environmental Assessment Division, Assessment and Information Services Center, National Environmental Satellite, Data, and Information Service with the cooperation of the Philippine government and the support of the U.S. State Department/Agency for International Development.

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REFERENCES and BIBLIOGRAPHY

Brand, Samson and Jack W. Blellock, (1976): Typhoon Havens Handbook for the Western Pacific and Indian Oceans. Naval Environmental Prediction Research Facility, Monterey, CA.

Gray, William M., (1970): A Climatology of Tropical Cyclones and Disturbances of the Western Pacific (With a Suggested Theory for their Genesis/Maintenance). Naval Weather Research Facility, Norfolk, VA.

International Monetary Fund, (1985): International Financial Statistics, Supplement on Exchange Rates. International Monetary Fund, Washington, DC.

JTWC, (Annual, 1970-84): Annual Typhoon Report. Joint Typhoon Warning Center (JWTC), Guam.

Office of Foreign Disaster Assistance, (1970-1984): Foreign Disaster Case Reports. Office of Foreign Disaster Assistance, Agency for International Development, State Department, Washington, DC.

Office of Foreign Disaster Assistance, (1982): The Philippines: A Country Profile. Office of Foreign Disaster Assistance, Agency for International Development, State Department, Washington, DC.

PAGASA, (Annual, 1979-83): Annual Tropical Cyclone Report. Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), National Weather Office, Quezon City, Philippines.

PAGASA, (1978): Tropical Cyclone Summaries from 1948 to 1978. Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Quezon City, Philippines.

"Typhoon! The great wind that spells catastrophe," Far Eastern Economic Review, 101 (September 29, 1978), 18.

Vreeland, Nena, Geoffrey B. Hurwitz, Peter Just, Philip W. Moeller and R. S. Shinn, (1982): Philippines, A Country Study. Department of the Army, Washington, DC.

World Bank, (1976): The Philippines. World Bank, Washington, DC.

World Bank, (1982): The Philippines: Selected Issues for the 1983-87 Plan Report. World Bank, Washington, DC.

Appendix A: Damage Assessment Tables (1970-1984)

Description of Table Format

1) Name of storm

TY = Typhoon
TS = Tropical storm

2) Day 1 of impact (Julian)

3) Length of impact (in days)

4) Areas impacted (coded)

0 - None reported
1 - N. Luzon
2 - C. Luzon
3 - S. Luzon
4 - C. Visayas
5 - Mindanao

5) Major cause of damage (coded)

0 - None reported
1 - Wind
2 - Rain/floods
3 - Storm surge
4 - Wind/rain
5 - Wind/rain/storm surge

6) Deaths (coded)

0 - None reported
1 - Under 100
2 - 100 - 300
3 - Above 300

7) Numbers affected (coded)

0 - None reported
1 - 1 - 1,000
2 - 1,000 - 100,000
3 - 100,000 - 1,000,000
4 - Above 1,000,000

8) Boat/ship damage (coded)

0 - None reported
1 - Small craft
2 - Small craft and ships

9) Crop damage* (coded)

0 - None reported
1 - Less than $1 million
2 - $1 million - $5 million
3 - Above $5 million

10) Public works/infrastructure* (coded)

0 - None reported
1 - Less than $1 million
2 - $1 million - $5 million
3 - $5 million - $10 million
4 - $10 million - $50 million
5 - Above $50 million

11) Total damages* (coded)

0 - None reported
1 - Up to $5 million
2 - $5 million - $50 million
3 - $50 million - $100 million
4 - Over $100 million

12) Damage rating

Coded "Deaths" +
Coded "Numbers affected" +
Coded "Total damages"

13) Wind speed 24 hours before landfall (kt)

14) Wind speed 12 hours before landfall (kt)

15) Maximum observed wind speed (kt)

16) Minimum sea level pressure (mb)

17) Angle of impact (direction from which storm tracks - reference is north and 90° is east)

1 - no cases
2 - no cases
3 - 195° to 225° and 15° to 45°
4 - 165° to 195° and 45° to 75°
5 - 135° to 165° and 75° to 105°
6 - 105° to 135°

18) Maximum point rainfall (mm) and WMO observation station number

19) Damage evaluation index (based on classification rating)--SIDE

1 = 0
2 = 1-3
3 = 4-5
4 = 6-8
5 = 9-11

* All damages assessed in $ for that year
( ) Estimate

1970 PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Nancy	53	5	1,2,3	1	1	1	2	1	1	1	3
TS Pamela	177	5	5	0	0	0	0	0	0	0	0
TS Ruby	191	7	4	0	0	0	0	0	0	0	0
TS Violet	217	5	2	0	0	0	0	0	0	0	0
TS Fran	246	5	3	2	1	1	0	1	1	1	3
TY Georgia	251	4	1,2	1	1	2	2	1	2	1	4
TY Joan	284	4	3	4	3	3	3	2	4	3	9
TY Kate	289	6	5	4	3	3	3	2	2	2	8
TY Patsy	321	3	3	5	3	3	3	2	5	3	9

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Nancy	115	120	118	960	6	204	446	2
TS Pamela			54	1001	5	235	653	1
TS Ruby			19	980	5	133	233	1
TS Violet			30	994	5	89	222	1
TS Fran			28	1004	3	76	328	2
TY Georgia	115	130	130	978	5	138	336	3
TY Joan	105	130	148	951	5	235	548	5
TY Kate	120	125	54	989	5	123	630	4
TY Patsy	125	135	108	955	5	205	446	5

Name of storm	Day of year (Julian)	Length of impact (day)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Wanda	112	6	3,4	1	1	1	1	1	1	1	3
TS Babe	123	5	3	0	0	0	0	0	0	0	0
TY Dinah	145	4	3,4	1	1	1	1	0	0	0	2
TS Emma	148	2	5	0	0	0	0	0	0	0	0
TY Freda	165	4	1	0	0	0	0	0	0	0	0
TY Gilda	175	3	3,4	4	1	1	1	0	0	0	2
TY Harriet	183	4	3,4	1	1	1	0	0	0	0	2
TY Jean	194	4	3,4	4	0	0	0	0	0	0	0
TS Kim	190	4	2,3	0	0	0	0	0	0	0	0
TY Lucy	189	4	1	4	0	1	0	0	0	0	1
TY Rose	225	3	1	0	0	0	0	0	0	0	0
TY Della	270	2	1	0	0	0	0	0	0	0	0
TY Elaine	276	3	3,4	3	0	2	1	0	0	0	2
TY Faye	281	7	2,3	0	0	0	0	0	0	0	0
TS Gloria	282	2	1	1	1	1	0	0	0	0	2
TY Hester	290	3	4,5	0	0	0	0	0	0	0	0

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Wanda	(30)	(40)	86	986	3	69		2
TS Babe			25	939	6	293		1
TY Dinah	(50)	70	81	979	5	120		2
TS Emma			40	1005	5	65		1
TY Freda	(40)	55	69	999	6	207		1
TY Gilda	(40)	60	81	983	5	190		2
TY Harriet	(30)	50	65	994	5	139		2
TY Jean	60	75	70	1005	5	180		1
TS Kim			27	1005	5	98		1
TY Lucy	125	120	102	926	(6)	380		2
TY Rose	95	105	75	986	5	145		1
TY Della	(30)	(30)	26	1002	5	72		1
TY Elaine	(30)	40	51	982	5	106		2
TY Faye	(30)	(30)	53	966	6	274		1
TS Gloria			42	973	5	274		2
TY Hester	(30)	35	54	991	5	86		1

PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Kit	006	7	3,4	5	2	2	2	3	4	2	6
TS Mamie	121	2	2,3	0	0	0	0	0	0	0	0
TY Ora	175	3	3,4	5	2	2	2	2	3	2	6
TY Susan	187	10	1,2,3,4	5	3	4	2	3	5	4	11
TY Cora	225	4	1,2,3	0	0	0	0	0	0	0	0
TY Elsie	243	3	3,4	0	0	0	0	0	0	0	0
TY Flossie	253	3	1	0	0	0	0	0	0	0	0
TS Grace	254	11	1,2	0	0	0	0	0	0	0	0
TY Lorna	291	5	1	0	0	0	0	0	0	0	0
TY Pamela	309	3	3,4	1	1	1	0	1	1	1	3
TY Sally	334	2	5	0	0	0	0	0	0	0	0
TY Therese	337	4	4,5	4	2	2	0	2	2	2	6

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Kit	70	120	56	993	3	189	328	4
TS Mamie								1
TY Ora	45	75	110	970	6	237	444	4
TY Susan	(20)	(25)	30	1000	6	131	328	5
TY Cora		(20)						1
TY Elsie		(15)			5			1
TY Flossie	(25)	(30)	19	1004	5	149	434	1
TS Grace	(30)	(20)	46	1004	5	23	440	1
TY Lorna								1
TY Pamela	(45)	65	80	989	5	234	132	2
TY Sally								1
TY Therese	60	65	60	997	5	200	630	4

1973 PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TS Wilda	180	3	1	0	0	0	0	0	0	0	0
TY Louise	244	3	1	0	0	0	0	0	0	0	0
TY Marge	253	3	1	0	0	0	0	0	0	0	0
TY Nora	279	4	1,2,3	5	1	2	2	1	1	1	4
TS Patsy	285	3	1	0	0	0	0	0	0	0	0
TY Ruth	287	3	2	1	1	1	0	1	1	1	3
TS Thelma	315	3	5	0	0	0	0	0	0	0	0
TS Vera	322	5	4	2	1	2	0	2	2	2	5

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TS Wilda	(15)	(20)	24	1004	5	64	135	1
TY Louise	(20)	(30)	58	996	4	147	133	1
TY Marge	(15)	(20)	48	1009	5	232	222	1
TY Nora	130	115	81	978	5	380	328	3
TS Patsy	95	75	43	1002	5	131	(232)	1
TY Ruth	60	70	98	972	6	332	329	2
TS Thelma	N/A							1
TS Vera	(20)	(25)	48	993	6	198	637	3

1974 PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Dinah	160	3	1,2	4	1	1	0	0	1	1	3
TY Ivy	190	3	1	5	2	2	1	1	1	1	5
TS Wendy	266	4	1	0	0	0	0	0	0	0	0
TY Bess	283	3	1	4	1	2	0	2	2	2	5
TY Carmen	288	3	1	4	1	2	0	2	2	2	5
TY Della	295	3	1	0	0	0	0	0	0	0	0
TY Elaine	300	3	1,2	4	1	3	1	3	3	2	6
TS Faye	304	3	3,4	0	0	0	0	0	0	0	0
TY Gloria	309	4	1	4	1	1	0	1	1	1	3
TY Irma	331	3	1,2	1	1	2	2	2	2	2	5
TS Kit	353	4	4	0	0	0	0	0	0	0	0

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Dinah	60	65	65	986	5	494	446	2
TY Ivy	75	90	91	973	5	142	328	3
TS Wendy	(20)	(30)	76	1000	6	380	135	1
TY Bess	60	65	125	979	6	781	328	3
TY Carmen	55	60	60	1001	6	186	328	3
TY Della	55	60	93	993	5	79	222	1
TY Elaine	85	95	145	959	5	679	328	4
TS Faye	(15)	(20)	52	955	5	209	546	1
TY Gloria	90	105	84	972	5	410	328	2
TY Irma	115	105	76	981	5	301	447	3
TS Kit	(20)	(25)	81	994	5	217	434	1

PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Lola	023	3	4,5	1	1	2	0	3	1	4	7
TY Alice	259	3	2	0	0	0	0	0	0	0	0

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Lola	55	65	59	985	5	102	333	4
TY Alice	45	65	62	984	6	174	333	1

1976 PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Olga	139	9	1,2	2	2	4	0	3	4	3	9
TY Ruby	175	9	1,2,3,4	4	1	2	0	2	2	1	4
TS Ellen	235	2	1	0	0	0	0	0	0	0	0
TY Iris	258	4	2	4	0	1	0	0	1	1	3
TS Nora	338	6	2,3	4	2	2	0	2	2	2	6

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Olga	55	65	81	981	5	605	328	5
TY Ruby	30	40	90	973	5	334	328	3
TS Ellen	(20)	(30)	30	994	5	115	133	1
TY Iris	(20)	(30)	46	984		157	324	2
TS Nora	(30)	(35)	50	995	5	167	444	4

PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TS Ruth	161	5	3,4	0	0	0	0	0	0	0	0
TS Sarah	197	3	3,4,5	4	1	1	0	1	1	1	3
TY Thelma	203	3	1,2	4	1	1	1	0	1	1	3
TS Carla	245	2	1	2	0	0	0	0	1	1	1
TY Dinah	257	7	1	4	1	2	1	0	1	1	4
TS Freda	266	3	1	0	0	0	0	0	0	0	0
TY Kim	316	6	1,2,3,4	5	2	2	1	2	2	3	7

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TS Ruth	(15)	(20)	81	976	5	44	430	1
TS Sarah	(20)	30	60		6	69	429	2
TY Thelma	60	70	81	967	6	391	135	2
TS Carla	(15)	(20)	35	992	5	88		2
TY Dinah	50	60	110	977	4	359	328	3
TS Freda	(20)	(25)	49	996	5	164	630	1
TY Kim	110	115	94	977	5	321	440	4

1978 PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Mary	1	3	4,5	0	0	0	0	0	0	0	0
TY Olive	109	3	3,4	4	1	2	1	3	3	2	5
TS Shirley	177	4	4	0	0	0	0	0	0	0	0
TY Elaine	235	4	1	4	1	1	0	2	2	2	4
TS Kit	264	4	2	0	0	0	0	0	0	0	0
TY Lola	269	4	3,4	5	1	2	1	2	2	2	5
TS Nina	282	7	3	4	1	2	1	2	3	2	5
TY Rita	298	4	2,3,4	5	3	4	2	3	5	4	11

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Mary	35	30	35	1007	5			1
TY Olive	35	45	97	962	6	222	543	3
TS Shirley	(20)	(20)	28	1002	5	131	630	1
TY Elaine	(20)	25	65	986	5	534	328	3
TS Kit	(20)	(20)	40	1000	5	65	548	1
TY Lola	30	30	108	987	5	276	546	3
TS Nina	(35)	(45)	78	985	5	275	429	3
TY Rita	145	135	67	988	5	304	434	5

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Cecil	104	7	1,2,3,4,5	5	1	3	1	3	4	2	6
TS Dot	130	7	3,4,5	0	0	0	0	0	0	0	0
TY Ellis	184	3	1	0	0	0	0	0	0	0	0
TY Irving	222	3	1,2,3	2	1	2	0	2	2	2	5
TY Mac	259	7	2,3,4	4	1	2	1	2	2	2	5
TY Sarah	277	8	2,3	4	1	2	1	1	2	1	4
TY Vera	308	4	2,3,4	5	1	2	1	1	1	1	4
TS Wayne	317	1	2	0	0	0	0	0	0	0	0
TS Ben	355	4	1,2,3,4	0	0	0	0	0	0	0	0

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Cecil	55	70	102	973	6	291		4
TS Dot	30	30	35	1001	5	129		1
TY Ellis	75	80	76	985	6	284		1
TY Irving	30	30	76	991		398		3
TY Mac	65	70	59	984	5	199		3
TY Sarah			54	998		236		3
TY Vera	135	140	64	971	6	235		3
TS Wayne	30	25	65	990		22		1
TS Ben	(30)	(30)	59	997	5	79		1

PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Dom	131	7	1,2,3,4,5	4	0	2	0	1	1	1	3
TS Forrest	144	4	1,2,3	4	0	2	0	0	1	1	3
TS Herbert	174	3	4	0	0	0	0	0	0	0	0
TY Joe	202	2	1,2	4	1	2	0	2	3	2	5
TY Kim	206	3	4	2	1	2	0	0	0	0	3
TS Cary	302	3	2,3	2	0	2	0	1	1	1	3
TY Betty	308	4	1,2,3,4	4	2	3	1	3	5	4	9
TS Ed	357	3	4,5	0	0	0	0	0	0	0	0

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Dom	45	55	78	993	5	730		2
TS Forrest	45	45	66	996	6	249		2
TS Herbert			27	1005		146		1
TY Joe	75	95	65	979	5	165		3
TY Kim	50	70	60	982	6	536		2
TS Cary	25	25	43	998	6	316		2
TY Betty	105	110	113	956	5	699		5
TS Ed	35	35	43	1003	3	103		1

PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Kelly	181	3	3,4	4	2	1	1	2	2	2	5
TS Lynn	183	3	2,3,4	4	1	2	0	1	1	1	4
TY Clara	261	4	1,2,3	5	1	3	2	2	3	2	6
TS Fabian	284	3	4,5	0	0	0	0	0	0	0	0
TS Hazen	322	4	2,3,4	1	1	1	1	1	1	1	3
TY Irma	327	4	1,2,3,4	5	2	3	2	3	4	3	8
TY Lee	358	4	2,3,4	4	2	3	1	3	4	3	8

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TS Kelly	25	30	81	989	5	110		3
TS Lynn	30	40	76	997	6	224		3
TY Clara	75	90	111	962	5	764		4
TS Fabian			24	1002		101		1
TS Hazen	55	60	115	981	5	115		2
TY Irma	130	115	140	950	6	287		4
TY Lee	80	90	89	951	5	179		4

1982 PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TS Mamie	78	3	4,5	1	1	2	1	1	1	2	5
TY Nelson	73	5	4,5	5	2	3	1	3	4	3	8
TY Pat	137	5	1,2,3,4	0	0	0	0	0	0	0	0
TS Winona	195	3	1,2,3	4	0	2	0	2	2	2	4
TY Faye	231	9	1,2,3,4	4	1	2	0	0	0	0	3
TS Irving	250	5	3,4,5	4	1	2	1	2	2	2	5
TY Nancy	286	3	1,2	4	1	3	2	3	4	3	7
TS Pamela	340	4	3,4	4	0	2	0	2	3	2	4
TY Roger	341	5	1,2,3,4	1	0	2	1	1	1	1	3

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TS Mamie	55	55	51	997	5	171		3
TY Nelson	85	95	100	986	5	195		4
TY Pat	30	35	78	998		148		1
TS Winona	40	50	59	993	6	321		3
TY Faye	(20)	(25)	119	987	5	217		2
TS Irving	55	60	62	981	5	238		3
TY Nancy	75	100	73	994	5	175		4
TS Pamela	55	60	38	999	3	70		3
TY Roger	(25)	(35)	67	992	6	317		2

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Sarah	172	2	4,5	0	0	0	0	0	0	0	0
TY Tip	190	2	3,4	4	0	0	0	1	1	1	1
TY Vera	194	4	3,4	1	2	3	1	3	4	3	8
TS Carmen	225	3	1	0	0	0	0	0	0	0	0
TY Ellen	248	3	1	1	0	1	1	1	1	1	2
TS Herbert	276	4	5	0	0	0	0	0	0	0	0
TY Joe	283	3	2	0	0	0	0	0	0	0	0
TY Kim	286	3	4	0	0	0	0	0	0	0	0
TY Orchid	321	11	1,2,3,4	4	1	2	2	3	4	2	5
TY Percy	326	2	4	0	0	0	0	0	0	0	0

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Sarah	(20)	(25)			5			1
TY Tip	(20)	25	73	993	5	242		2
TY Vera	50	60	89	983	6	254		4
TS Carmen	30	30	40	999		218		1
TY Ellen	95	120	100	989	5	218		2
TS Herbert	(20)	(25)	19	1005		226		1
TY Joe	(20)	(25)	65	1000	6	119		1
TY Kim	(20)	(20)		1004	5	83		1
TY Orchid	50	40	81	988	2	340		3
TY Percy	35	30	59	985	3	85		1

PHILIPPINE TROPICAL CYCLONE DAMAGE AND METEOROLOGICAL VALUES

Name of storm	Day of year (Julian)	Length of impact (days)	Area impacted (coded)	Major cause of damage (coded)	Deaths (coded)	Numbers affected (coded)	Boat/ship damage (coded)	Crop damage (coded)	Public works/ infrastructure (coded)	Total damage (coded)	Damage rating (coded)
TY Alex	182	3	1	0	0	0	0	0	0	0	0
TS Betty	185	4	1	0	0	0	0	0	0	0	0
TS June	241	3	1,2	2	1	2	0	0	0	0	3
TY Ike	244	5	4,5	1	3	4	2	3	5	4	11
TY Warren	297	9	2,3	4	1	2	2	0	0	0	3
TY Agnes	308	4	4	5	3	3	2	3	3	3	9
TY Bill	319	9	1	0	0	0	0	0	0	0	0

Name of storm	Wind speed -24 hr (kt)	Wind speed -12 hr (kt)	Max. wind (kt)	Min. SLP (mb)	Angle of impact (coded)	Max. rainfall amt. (mm)	sta. #	Damage evaluation index (coded)
TY Alex	(20)	(25)	N/A	N/A		N/A		1
TS Betty	(20)	(25)	N/A	N/A	5	N/A		1
TS June	(20)	30	N/A	N/A	5	N/A		2
TY Ike	90	110	N/A	N/A	5	N/A		5
TY Warren	(20)	(20)	N/A	N/A	5	N/A		2
TY Agnes	110	115	N/A	N/A	5	N/A		5
TY Bill	110	90	N/A	N/A		N/A		1

Appendix B: Economic Damage Summaries (1970-1984)

1. ECONOMIC DAMAGE SUMMARY: 1970

The typhoons of 1970 were significant in causing human suffering, damaging public works, and disrupting normal activities. In particular, TY Patsy caused flooding, the uplifing of ships from Manila harbor onto the streets, and extensive damage to public structures. Crops were damaged by all typhoons of the year, but not to the extent of impacting total production of rice and corn (see Table B-1). Coconut trees and bananas in Mindanao were significantly damaged by TY Kate. In addition to the damage to public works/infrastructure caused by Patsy, TY Joan caused significant damage in this category, including that to dams.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1970)
TY Nancy	1.0
TS Fran	1.0
TY Georgia	1.4
TY Joan	73.0
TY Kate	12.5
TY Patsy	97.7
TOTAL	186.6

2. ECONOMIC DAMAGE SUMMARY: 1971

Although the tropical cyclone season spawned many storms in the Philippine area, no individual cyclone caused any substantial areal damage. The extent of damage was local with minor flooding and mudslides. Total damage to the Philippine economy for 1971 from these tropical cyclones is estimated at under $5 million.

3. ECONOMIC DAMAGE SUMMARY: 1972

For the Philippines 1972 proved to be a year of devastating destruction due to tropical cyclones and monsoons, a year in which disaster quickly followed disaster. The typhoon season opened early when on January 6 TY Kit took a heavy toll in crops and property in the Central Visayas. Many bridges were washed away by flood waters.

The next major storm was TY Ora in late June. Manila was particularly hard hit. Electric power, water supply, telephone service, and sewers were knocked out. Ships in Manila harbor were carried ashore by wind and storm surge. Unfortunately, Central and Southern Luzon did not have time to recuperate from the destruction of TY Ora and immediately monsoonal rains began to fall and their continuance was attributed to another tropical cyclone, TY Susan. Although TY Susan crossed the Philippines as a tropical disturbance in early July, it influenced the monsoonal flows (and also interacted with TY Rita, which, although it did not cross the Philippines, affected the weather) and kept the rains falling.

Table B-1.--Selected Philippine Grain Production 1970-71 - 1984-85 (in 1000 metric tons).

Year	Corn	Rice
1970-71	2,012	5,235
1971-72	2,024	4,997
1972-73	1,843	4,362
1973-74	2,258	5,571
1974-75	2,514	6,056
1975-76	2,717	6,643
1976-77	2,775	7,016
1977-78	2,796	7,552
1978-79	3,090	7,513
1979-80	3,123	7,835
1980-81	3,110	7,723
1981-82	3,290	8,110
1982-83	3,126	7,731
1983-84	3,346	7,841
1984-85	3,373	8,150

Source: U.S. Department of Agriculture.

Rain fell from late June through early August (a period of over 40 days); in Central Luzon a single month's rainfall (July) exceeded the normal total annual rainfall for the area.

The cumulative human suffering, crop loss, and property damage (particularly to public works/infrastructure) from the period beginning with Ora and continuing through early August was overwhelming. The major crop damage from the two-month period of devastation centered in Northern and Central Luzon but the Eastern Visayas were also impacted. For the year 1972, rice production dropped from approximately 5.0 million metric tons in 1971 to 4.4 metric tons in 1972, a drop of almost 13 percent. Corn production went from about 2 million metric tons to 1.8 metric tons, a drop of 9 percent (see Table B-1). In the early 1970's the Philippines consumed all the domestic production of rice. The loss of the rice crop was particularly devastating to the Philippine population itself. Not the least of the impacts of the floods was damage to the rice-growing land itself as flood-waters deposited mud, silt, and debris on it. Damage to public works was also substantial. Roads and bridges were destroyed; flood control and irrigation systems damaged; classrooms destroyed. The New York Times reported on September 23, 1972 that the United Nations disaster relief coordinator estimated that total damage was $225 million but that when private and public losses were added up the figure would probably be exceeded. Interpreting this figure, it can be reasonably assumed that well over half the losses were to public property, putting an estimate of damage in this category between $100 million and $150 million.

In early December, TY Therese tracked across the northern tip of Mindanao, principally Misamis Oriental province where damage was mainly from flooding which destroyed homes.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1972)
TY Kit	23.0
TY Ora	15.0
TY Susan	225.0
TY Therese	10.0
TOTAL	273.0

4. ECONOMIC DAMAGE SUMMARY: 1973

The year's tropical cyclones caused only a fraction of the damage that had been done in the previous year. The major storm was TS Vera which, with a combination of strong winds and heavy rains, caused considerable damage along a swath across the Visayas, an area with an estimated population at the time of over 3.4 million.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1973)
TY Ruth	5.0
TY Nora	2.0
TS Vera	10.0
TOTAL	17.0

5. ECONOMIC DAMAGE SUMMARY: 1974

Of the 11 typhoons and tropical storms which tracked over the Philippines in 1974, 9 tracked through Northern Luzon, bringing a good deal of damage to the area, both to property and crops. All of those storms with reported damages tracked through this area although some of the impacts were also felt further south.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1974)
TY Dinah	1.0
TY Ivy	2.0
TY Bess	9.2
TY Carmen	11.6
TY Elaine	21.0
TY Gloria	3.2
TY Irma	7.3
TOTAL	55.3

6. ECONOMIC DAMAGE SUMMARY: 1975

The only tropical cyclone to cause reported damage in the Philippines in 1975 was TY Lola, but the damage inflicted by this storm was significant to the Philippine economy. Lola hit the rich sugar-producing area in the Visayas (Cebu, Negros, etc.) with peak winds of over 75 mph in late January. The destruction to the crop was substantial. In 1975, Philippine sugar was a mainstay of the world sugar market. On January 28, 1975, the New York Times reported that the damage to the Philippine crop had brought an increase in sugar future prices. The Philippines banned the export of sugar until mid-February. Total exports of centrifugal sugar declined from 1,542,000 metric tons in 1974 to 972,000 metric tons in 1975 while the value of a unit rose from $478 to $597 (see Table B-2). The value (in current prices at year of sale expressed in U.S. dollars) dropped from $737 million in 1974 to $581 million in 1975, a net loss of $156 million.

Table B-2.--Volume and Unit Value of Selected Philippine Commodity Exports.

Category	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Volume (in 1000 metric tons)										
Copra	926	734	268	761	823	635	365	145	121	108
Coconut oil crude	461	427	415	606	854	714	962	743	873	984
Dessicated coconut	76	78	64	66	81	98	91	86	87	86
Copra meal or cake	352	263	271	303	498	436	535	548	545	620
Sugar, centrifugal	1,224	1,470	1,542	972	1,456	2,419	1,124	1,150	1,602	953
Pineapple, canned	108	91	125	116	138	154	162	189	187	173
Bananas	422	466	663	823	796	693	776	859	923	869
Unit Value (US$ per metric ton)										
Copra	119	226	522	226	182	316	372	616	389	311
Coconut oil crude	180	354	916	373	345	532	608	919	615	509
Dessicated coconut	231	416	944	459	463	919	902	1,247	1,331	1,179
Copra meal or cake	46	86	103	110	110	133	129	156	149	130
Sugar, centrifugal	172	186	478	597	293	210	175	184	348	436
Pineapple, canned	181	217	244	298	338	362	370	391	439	508
Bananas	58	60	69	89	95	105	108	113	124	143

Source: World Bank, The Philippines, Selected Issues for the 1983-87 Plan Period (1982).

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1975)
TY Lola	160.0
TOTAL	160.0

7. ECONOMIC DAMAGE SUMMARY: 1976

The tropical cyclone damage in 1976 was limited to that from two storms, TY Olga and TS Nora. However, in money terms, the damage and impact were great. Olga, which hovered near Luzon for several days and then meandered across the island, brought heavy rains which set off severe flooding. A major dike 60 miles north of Manila collapsed, flooding homes and destroying roads and bridges. Northern Luzon received the worst damage from the storm. A final count of those killed was 274 with over 2.7 million affected. Damage done to rice, corn, tobacco, livestock and poultry was estimated at $49.5 million. Estimated damage to public works and to national and local highways was $35.5 million. The immediate need to rebuild roads, bridges, damaged power lines, and irrigation and flood control projects placed great demands on the Philippine economy. In early December, TS Nora inundated the Bicol and the Eastern Visayas with heavy rains, rendering people homeless and doing some crop damage.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1976)
TY Olga	85.0
TS Nora	9.0
TOTAL	94.0

8. ECONOMIC DAMAGE SUMMARY: 1977

Although Northern Luzon was impacted by 5 of the 7 tropical cyclones which tracked over the Philippines, the year's total damages were not great and no exceptional crop or property loss can be attributed to them. The single most destructive storm was TY Kim which not only caused 55 drownings but also, in a freak occurrence, caused the tipping over of a candle in a Manila hotel that set off a fire killing 47 persons. Considerable property and crop damage were attributed to Kim.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1977)
TS Sarah	.6
TY Thelma	.5
TY Dinah	2.8
TY Kim	61.8
TOTAL	65.7

9. ECONOMIC DAMAGE SUMMARY: 1978

The damage from tropical cyclones to the Philippine economy was substantial in 1978. All of the Republic's areas experienced property damage, but Southern Luzon and the Visayas were impacted by the storms doing the greatest damage. TY Rita was the most devastating. Although a downturn in sugar prices can be identified as a major cause of the decrease in centrifugal sugar exports in this year, it cannot explain all of the drop from 2,419,000 metric tons in 1977 to 1,124,000 metric tons in 1978, a decrease of almost 50 percent. Part of this drop must be explained by storm losses from wind and rain damage to sugar through the year. In this regard, TY Rita was the most significant storm. The price drop in the world sugar market coupled with lowered export volume meant a drop in income earned by sugar exports from $506 million in 1977 to $197 million in 1978, a 60 percent decline (see Tables 2 and B-2).

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1978)
TY Olive	33.1
TS Shirley	11.9
TS Kit	8.7
TS Nina	11.9
TY Rita	115.0
TOTAL	180.6

10. ECONOMIC DAMAGE SUMMARY: 1979

The most damaging storms of the 1979 season were TY Cecil and TY Mac, both of which impacted the sugar-producing areas of the Visayas. Despite the fact that sugar exports remained at the low level of the previous year, only a marginal part of this situation can be attributed to storm damage. The market conditions were the larger cause.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1979)
TY Cecil	36.1
TY Irving	6.0
TY Mac	9.8
TY Sarah	2.5
TY Vera	.8
TOTAL	55.2

11. ECONOMIC DAMAGE SUMMARY: 1980

Damage from tropical cyclones in this year centered on Luzon. All 5 storms with monetary damages assessed tracked across Luzon and, generally, caused damages throughout the island. Most damage came from flooding from torrential rains. Parts of metropolitan Manila were under water several times during the year. TYs Joe and Kim followed shortly after the other in mid-July and compounded the damage since Kim dumped rain on already wet ground. Both caused rivers to overflow and to trigger mudslides. Damage from Kim is included in the assessed damage for TY Joe. Sometimes those who do assessments of storms that overlap cannot distinguish the damages of one from the damages of the other. Therefore, they record the damage for two storms under one name.

The singlemost destructive storm of the year was TY Betty which slammed into Central Luzon with winds in excess of 135 mph on November 4 and carried heavy rains with her. Over 100 people were reported dead, most of them from drowning. The Cagayan Valley in Northern Luzon lost most of its rice crop due to the floodwaters which rose to rooftop level in some areas. Officials viewing the scene from the air described the valley as looking like a sea. Estimates of the Philippine government placed the damage from TY Betty at over $178 million.

The cumulative effects of the storms of 1980, particularly Joe, Kim and Betty, were seen in the overall production of rice. Rice production, which had been generally increasing in volume since the disastrous typhoon-monsoon season of 1972, took a slight drop in 1980, falling over 100,000 metric tons from 1979 (see Table B-1).

The destructive tropical cyclones of 1980 also took their toll in damage to public property, indeed the greatest monetary loss was here. Bridges, roads, irrigation projects, dikes, public buildings, and power lines all needed repair or replacement as flooding and mudslides tore them apart.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1980)
TY Dom	.3
TS Forrest	.1
TY Joe	13.4
TS Cary	.2
TY Betty	178.3
TOTAL	192.3

12. ECONOMIC DAMAGE SUMMARY: 1981

The year saw widespread human suffering, crop, and property damage following quickly after the previous year's devastation. In 1981 the center of the worst destruction was in Southern Luzon, the Bicol, and the Visayas. The destruction came not only from tropical cyclone activity but also from from strong monsoonal rains sometimes induced by the tropical cyclone activity.

The sugar-producing areas were particularly hard hit by storm activity. Exported centrifugal sugar took a precipitous drop from already falling levels even though price per metric ton rose from $348 in 1980 to $436 in 1981. The drop in sugar exports was from 1,602,000 metric tons in 1980 to 953,000 metric tons in 1981 (41 percent). The value of the exported sugar dropped from $557 million in 1980 to $416 million in 1981, a 25 percent drop in income (see Table B-2).

Damage to public works/infrastructure was again a major factor in tropical cyclone impact.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1981)
TY Kelly	7.7
TS Lynn	1.0
TY Clara	12.8
TS Hazen	.3
TY Irma	70.3
TY Lee	72.3
TOTAL	164.4

13. ECONOMIC DAMAGE SUMMARY: 1982

While 1982 did not produce any typhoons/tropical storms which devastated the Philippines, the cumulative damage for the year was considerable and fairly widespread, with two typhoons, Nelson and Nancy, doing most of the damage. TY Nelson tracked through the sugar-producing areas in late March damaging crops and in early September TY Irving went through the same area. In mid-October, TY Nancy hit Northern Luzon with high winds and heavy rains inflicting heavy damage to crops and public works.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1982)
TS Mamie	5.2
TY Nelson	69.0
TS Winona	9.9
TS Irving	10.8
TY Nancy	68.2
TS Pamela	11.9
TY Roger	.1
TOTAL	175.1

14. ECONOMIC DAMAGE SUMMARY: 1983

The year's two most destructive storms, TYs Vera and Orchid, impacted Southern Luzon and the Visayas, particularly Samar, inflicting both crop and property damage. TY Orchid never made landfall but, remaining parallel to the Philippine coast, she carried high winds and rain and churned the seas. This caused damage to fishing boats and to larger ships as well.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1983)
TY Tip	.2
TY Vera	33.3
TY Ellen	.6
TY Orchid	37.3
TOTAL	71.4

15. ECONOMIC DAMAGE SUMMARY: 1984

The year brought staggering loss and devastation to the Philippines from tropical cyclones. Described as the worst typhoon of the century, TY Ike with surface winds of over 145 mph struck the northernmost tip of Mindanao on September 1, continued its destructive course directly through Bohol, Cebu and Negros, and then took a course north through the Sulu Sea, striking the Calamian Group. The hardest hit province was Surigao del Norte in northern Mindanao where over 1,000 people died. The number of people in the Philippines left homeless was well over 300,000, and the number impacted over 1 million. An estimated 90 percent of the coconut trees spread over Surigao del Norte were destroyed. Additionally, there was damage to sugar canes, banana, pineapple, and other crops. Public works were also hard hit. The most serious destruction in Mindanao and the Central Visayas was to power and communication lines, buildings, and other basic structures. Roads and bridges were also destroyed.

The destruction from Ike was made more difficult for the Philippine government to deal with because a few days earlier TS June struck the northernmost tip of Luzon. Heavy rains from the combination of June and the southwest monsoon caused extensive flooding throughout much of Luzon, particularly along the west coast of Luzon and in the river valleys. At least 67 deaths were attributed to June, mainly from flooding and the accompanying mudslides. Rice, fruit trees, and livestock were destroyed.

In November another major tropical cyclone hit the Visayas. On November 5, TY Agnes hit Samar with winds around 123 mph, skirted Leyte, and moved through Cebu, Panay, and Buguanga Island. Storm-surge flooding of low-lying coastal areas of the islands of Samar and Leyte was particularly severe. Heavy rainfall also brought extensive flooding. The final death count was around 1,000. Banana and coconut trees were damaged as were other crops.

TYs Ike and Agnes damaged the major foreign exchange crops of the Philippines while TS June devastated rice and other food crops. Taken together with extensive damage to public works caused by Ike and Agnes (estimated at over $22 million and $9 million, respectively), the three storms made the year 1984 a much more difficult one for the Philippine economy.

SUMMARY

NAME OF STORM	TOTAL ESTIMATED $ DAMAGE (IN MILLION $/1984)
TY Ike	125.3*
TY Agnes	96.5
TOTAL	221.8

*Due to the methods by which assessment of damages were presented in published reports, the damages from TS June are included in those for Ike.

Appendix C: Peso Conversion Table

Table C-1.--Value of Philippine Peso to U.S. Dollar, 1970-1984.

	Market Rate/Par or Central Rate
Year	Peso per U.S. Dollar
1970	6.435
1971	6.435
1972	6.781
1973	6.730
1974	7.065
1975	7.498
1976	7.428
1977	7.370
1978	7.735
1979	7.415
1980	7.600
1981	8.200
1982	9.171
1983	14.002
1984	19.760

Source: International Monetary Fund, International Financial Statistics, Supplement on Exchange Rates (1985).